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High Efficiency Steam Installations for Ship-Propulsion, with Special Reference to the Question of Auxiliary Machinery.

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READ

On Tuesday, February 2, *at* 6.30 *p.m.*

CHAIRMAN: ENGINEER REAR-ADMIRAL W. M. WHAYMAN, C.B., C.B.E.

The CHAIRMAN: I have great pleasure in introducing Mr. Cook, of the Parsons Marine Steam Turbine Company, Ltd., to you this evening. I am sure you will all be very much interested in the subject matter of his paper, especially as regards the comparative data he has prepared, relating to the steam turbine installation versus other methods of propulsion.

Mr. COOK:

SECTION 1.

It is noteworthy that most of the papers which have been devoted in recent years to subjects relating to power production, whether for service on land or for the propulsion of vessels, have had for their keynote the question of thermal efficiency, which indicates that at the present time every avenue is being explored that promises to lead to improvement of efficiency.

Developments in land installations of steam turbines for the generation of electric power have brought into prominence the value of securing, by improvement in practice, a conversion of heat into mechanical energy on the highest scale of efficiency that thermodynamic laws allow. Reference need only be made to the paper by the Hon. Sir Charles A. Parsons at the World Power Conference, in which are given the thermal efficiencies attainable in steam plant under practical conditions by the use of high boiler pressures and temperatures, with cycles of operation following known thermodynamic principles, and in which paper it is shown that with such steam plant thermal efficiencies from fuel to electricity can be realised equal to 30%, and fuel consumptions as low as ·45 lbs. of oil per B.H.P. hour. In that paper an actual installation is described of a turbine plant of 50,000 K.W. capacity in which results in the neighbourhood of these figures are expected to be obtained.

Such results are made possible with maximum temperatures within safe values for present-day materials, by using known practical means of increasing the available energy per pound of steam, viz., higher boiler pressure, increased vacuum, interstage reheating of the steam and cascade feed heating.

A review of the history of the steam turbine in marine propulsion discloses the fact that during the past 20 years there has been an increase in overall efficiency of practically 100%, made up of improvements in turbine efficiency and propeller efficiency principally through the introduction of gearing between turbine and propeller, and an increase of available energy of the steam due to the use of superheat.

The use of mechanical gearing has now enabled turbines in marine propulsion to be designed with the maximum efficiency of conversion of the available energy of the steam as on land, and following the lead of land turbines it is now being sought to realise the considerable improvement which is attainable on further increasing the available energy per pound of steam, by the use of higher steam pressures and temperatures and by regenerative heating of the feed water by previously expanded steam.

Many concrete designs for such installations have been worked out. Two examples for total outputs of 27,000 S.H.P. and 13,500 S.H.P. were described in a paper* read by Sir John Biles at the meetings of the Institution of Naval Architects last year, and comparisons made on an economic basis with installations of other types for the same vessel, principally with Diesel Engines, to the advantage of the high efficiency steam turbine plant.

* "Relative Commercial Efficiency of Internal Combustion and Steam Engines for High Speed Passenger Vessels."

The most efficient arrangement of marine turbines in recent installations is recognised to be one consisting of three or more turbines in series grouped around a common gear wheel through which their power is transmitted to the propeller shaft. With this type of installation, the turbines run at a high speed of rotation and a high relative blade speed, and at the same time are of moderate size, easily overhauled and of rigid construction. Such an arrangement has therefore been retained for the new designs with their greater range of expansion. Figure 1 is an illustration of an arrangement of this type.

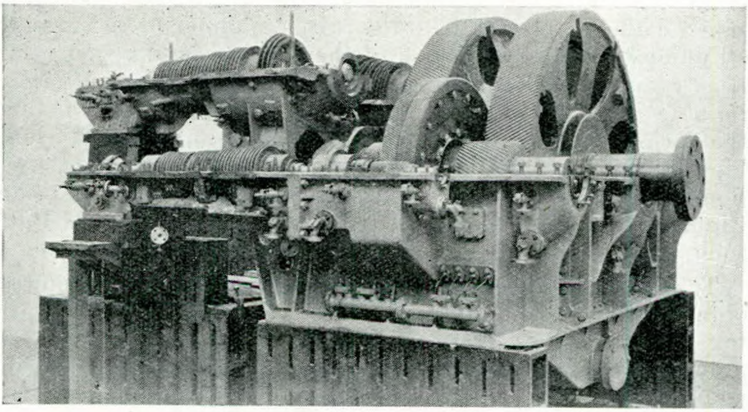


Fig. 1.

Section 2.

Since economy in the total fuel consumption is the ultimate aim, whilst the highest efficiency of conversion of heat into power is necessary on the part of the main engines that propel the vessel, equal consideration must be given to the question of auxiliary machinery which, with the improvements that have been made to reduce the consumption of the main machinery, is now responsible in a complete installation for a very appreciable percentage of the total fuel consumption. Wasteful auxiliary machinery either through unsatisfactory provision in the first place or through want of care in its maintenance and management, has not infrequently in the past been the cause of a poor overall performance, for which the propelling machinery has been blamed.

Mr. Archibald Gilchrist has cited* a case of excessive auxiliary consumption. He states " In another vessel where lack of economy was apparent, after the introduction of water-meters in order to localise the inefficiency, it was found that the auxiliaries were using 44 per cent. of the total steam used by the main engines. After these auxiliaries were thoroughly overhauled and put in good working order, the consumption dropped to about 15 per cent. of the steam used by the main engines."

The auxiliary machinery includes pumps for feeding the boilers, air and circulating pumps for the condensing plant, fans for the supply of air to the furnaces under forced draught, oil pumps for the lubrication of the bearings and gearing; and it is of vital importance that all of these should be entirely reliable in operation. Although the power required to drive the various pumps is small, their rate of consumption is usually high. In direct acting pumps for example the steam is used non-expansively, and a high efficiency cannot be expected. Figure 2 is a typical curve of consumptions per B.H.P. for such pumps.

The effect upon the total fuel consumption is not however obtained by simple addition of the auxiliary steam consumption to that of the main turbines. It is generally the practice to exhaust the steam of the auxiliary engines against a back pressure a few pounds above atmospheric, which enables the heat of this steam to be re-utilised for feed heating. The feed heater in fact fulfils the rôle of a condenser for the auxiliary exhaust steam, with this difference, that the cooling fluid in this case being the feed water itself, the heat that it absorbs is not lost to the system.

In all modern installations as much as possible of this heat is recovered in the feed heater, and it is sometimes held, because the heat of the auxiliary exhaust steam can be re-utilised in this way for heating the feed water, that the actual cost in fuel consumption for driving the auxiliary machinery is small. This, however, is not a true view of the case, since there are two other economical means of supplying the required low grade heat to the feed water.

The first of these has frequently been employed in land installations. Although it has no exclusive claim to the name, it

* Discussion on Paper "Notes on the Economical Performance of Turbine Installations in Merchant Ships," by Mr. T. G. Potts, before the North-East Coast Institution of Engineers and Shipbuilders, 1923.

has succeeded in being known as the economiser, which is presumably evidence that it was the first practicable means adopted for the purpose in question. In the economiser the feed water

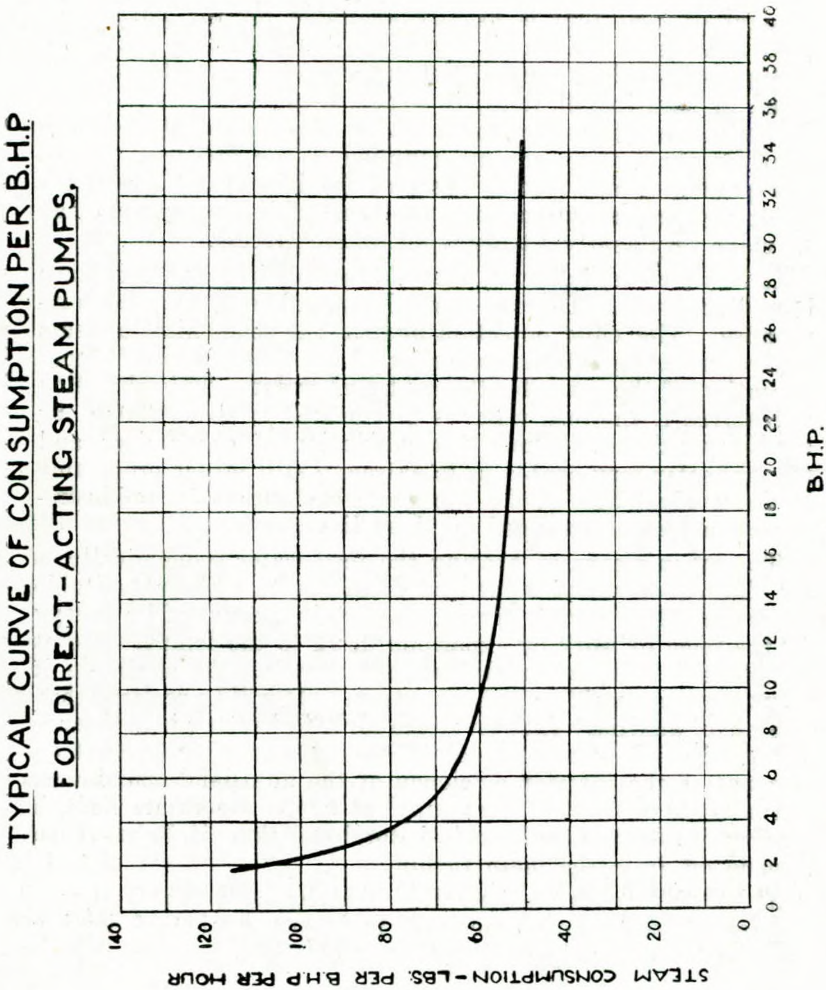


Fig. 2.

is heated by passing through a group of tubes situated in the uptake of the boilers over the outside of which the gases of combustion flow on their way to the chimney. Since the heat carried away in the chimney is to a great extent a measure of the inefficiency of the boilers, it is easiest to appreciate the advantage of the economiser by regarding the cold feed water as a means of cooling the chimney gases. The economiser is not used in marine installations, partly because of the large amount of heat that is usually available for the purpose of feed heating in the auxiliary exhaust steam, and partly on account of the large space that an economiser would require. Even in land installations, it is now being recognised that a better means of cooling the chimney gases is to utilise their heat for pre-heating the air supplied to the furnaces. Since the quantities and specific heats of the incoming air and the outgoing gases are practically the same, this arrangement can be made very nearly a truly regenerative process.

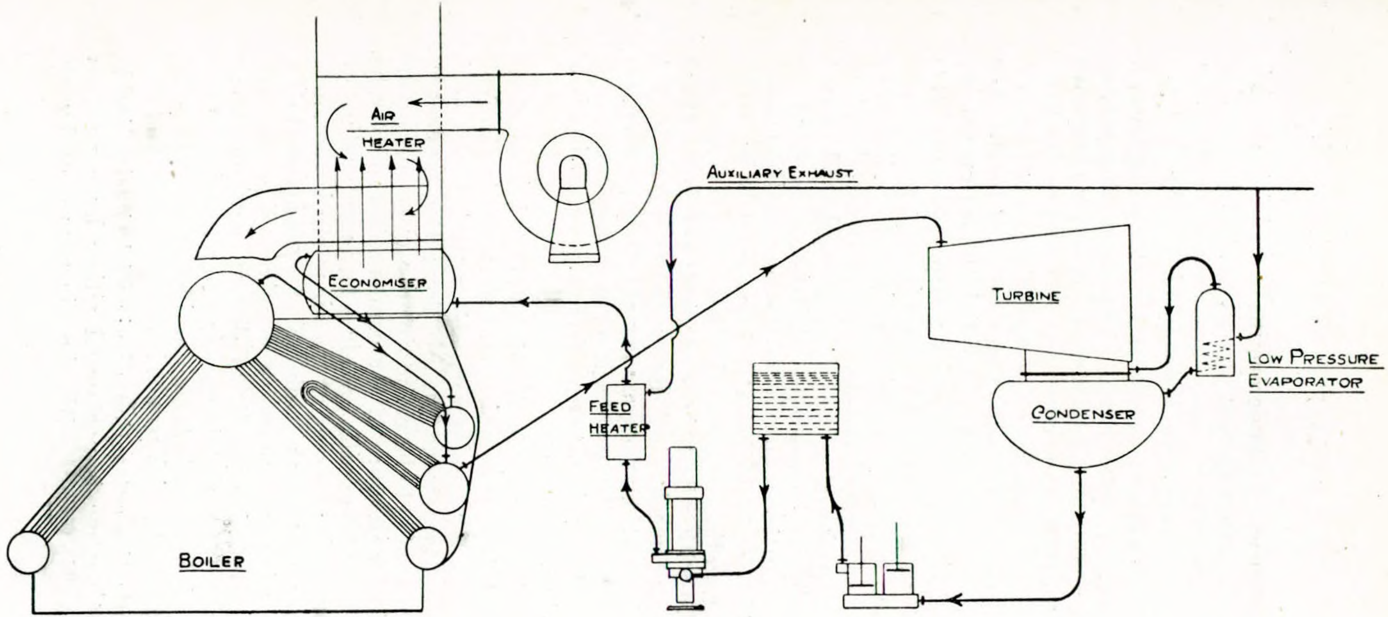
It is not clear, however, that the economiser ought to have been abandoned. There seems to be room here for a good compromise. The chief objection against the economiser appears to have been the external corrosion of the tubes due to the condensation of the gases by the cold feed water. This objection is removed if the feed water is first heated to about 200°F. by auxiliary exhaust steam. A combination of economiser and air preheater may enable us to extract a still larger proportion of the residual heat of the flue gases. Figure 3 is an illustration of a system arranged on these lines.

The other means of heating the feed water economically is by the use of steam tapped off from the turbines at suitable pressures, after having given up a certain amount of its energy in the form of work by expansion down to the temperature at which it is required, and that method would be available if there were no auxiliary exhaust steam. It will be realised that the use of auxiliary exhaust steam for feed heating is in essence an application of this principle, the difference being that on account of the inferior efficiency of the auxiliary machinery, for a given amount of heat supplied to the feed water, much less work is obtained from it beforehand than if it had been tapped off from the main turbines.

It will therefore be seen that it is by no means a simple matter to assess the true cost in fuel consumption of driving the auxiliary machinery.

Section 3.

While it is not the purpose of this paper to describe in detail the auxiliaries which are essential for the efficient operation of the propelling machinery and the service of the ship under



Marine Turbine Installation.

Diagram of an Efficient Arrangement for Air Heating and Feed Heating.

Fig 3

voyage conditions, but merely to determine the addition which they make to the fuel consumption, it will assist towards this end to enumerate briefly the various components with attention to the conditions which bear upon the subject of this enquiry.

First in order of importance is the boiler feed pump. Although treated as an auxiliary it is an indispensable part of the heat engine, in that, along with the air pump, it completes the steam cycle by raising the condensed steam to boiler pressure. In a large installation it is operated under float control so as to keep the water in the boilers at a constant level. For the sake of simplicity of control and reliability of operation, the slow direct-acting vertical type of pump is usually preferred. The relative diameters of steam pistons and plunger are such that the pump can work easily against the boiler pressure. The water pressure and the steam pressure are therefore inter-related and excessive pressure in the pump barrel cannot under any circumstances be reached. Admission of steam to the steam cylinder continues nearly to the end of the stroke, so that this engine works practically non-expansively. The available energy per lb. of steam is little more than half of what it would be with adiabatic expansion; and if we allow for condensation and mechanical losses the best result that can be expected with a steam pressure say of 200 lbs. per square inch and back pressure 10 lbs. gauge, is a consumption of about 45 lbs. per B.H.P. The exhaust steam from this pump is available for feed heating.

Next in order of importance is the air pump. Inasmuch as a portion of its work is to pump the condensate up to the feed tank, it is, as regards the condensate, also a part of the heat engine. It has also to remove the air from the condenser, which if a good vacuum is to be maintained in close correspondence with the vapour pressure of the condensate can only be done by withdrawing along with the air a large proportion of vapour. The volumetric capacity of the air pump is therefore usually many times that of the volume of condensate to be extracted, and the air pump regarded merely as a condensate pump has but a low efficiency. Some care is required at the hands of the engineers to maintain the air pump running at the best revolutions, high enough to maintain the vacuum, but avoiding excessive speed which would involve waste of steam.

In modern plants the extraction of air with its inevitable accompaniment of vapour is performed either by a vacuum augmentor working in series with the air pump, or by an independent set of ejectors in series, and in the latter case a rotary pump may be employed for the extraction of the condensate.

The steam engine operating the air pump is usually also of the direct-acting type, and involves a large rate of consumption per B.H.P., but the B.H.P. is difficult to assess, since in this case it depends upon the volumetric capacity of the pump rather than upon the duty it has to perform.

The circulating pump has the simple duty of pumping a certain quantity of cooling water against a head, which depends chiefly upon the resistance of the condenser tubes and circulating pipes, and which in a modern cargo vessel is of the order of 15ft. This pump is usually driven either by a simple engine with about 65% cut off, or by a compound engine. The latter is of course the more economical. If it is desired to utilise the exhaust steam for feed heating, it is allowed to exhaust against a back pressure, but where sufficient exhaust steam is available otherwise for feed heating, the circulating pump engine may be best arranged to exhaust to a vacuum. Care must be exercised by the engineer to avoid running this pump at too high a speed, since its power and therefore the steam consumed, will rise practically as the cube of the speed.

Fans are necessary for the supply of air to the boiler furnaces, under a slight pressure. These too, may be driven by compound engines, exhausting either against a back pressure or to vacuum. Their duty in air horse power is easily calculated from the quantity of air required for the furnaces, and the air pressure at the fan. It is important that circulating pumps and fans should be designed as nearly as possible for the conditions under which they are to be employed, that their output characteristic may be at the point of maximum efficiency.

Another indispensable accessory is the oil pump, for supplying lubrication to the bearings. Such pumps have to work against a considerable head, in order to be able to force the oil through the oil coolers and still leave a good pressure of supply to the various bearings. The head provided for is usually about 50 lbs. per square inch, and for a geared turbine installation the quantity of oil required to be circulated is roughly speaking two gallons per hour per S.H.P. These also are direct-acting steam pumps, and being small they have a steam consumption not less than about 60 lbs. per B.H.P.

In an oil burning installation there is also required a pump for the supply of oil fuel to the burners at the requisite pressure, and in a coal burning ship an ash hoist or ash ejector. These require to be supplied with a small amount of steam.

A steering engine, electric light engine, bilge, sanitary and general service pumps working as required are necessary for the service of the ship, and the steam that has to be supplied is included in the auxiliary consumption. The amount of this additional steam can only be based on service experience.

A certain amount of steam is continually being lost to the system through leakage of various sorts, and this must be included in the total consumption. Further, this implies a corresponding loss of feed water, which must be replaced from the reserve fresh water or by the distillation of sea water. The latter involves an expenditure of steam from 1·25 times to twice the amount of water distilled, which expenditure must also be included in the total consumption. The steam thus used for evaporation is condensed in the evaporator coil and returned to the system as hot-water, whilst the distillate can be condensed either separately or in the feed heater.

Section 4.

For reliable data as to the consumption of the most important auxiliaries, reference may be made to a paper by Mr. T. G. Potts*, read before the North-East Coast Institution of Engineers and Shipbuilders in 1923, describing measurements which were made on sea trials, using measuring tanks with a water meter in addition for the main condensate and a second smaller water meter for the condensate of the auxiliary steam. These measurements were made at varying output of the main engines, during the contractors' trials, and measurements continued with water meters during subsequent voyages of the vessel, over a total distance of 50,000 miles.

A smaller meter was subsequently installed to measure small quantities of condensate from the winch condenser, so that the consumption of any auxiliary engine which could be separately exhausted to the winch condenser could be measured at any time. In the vessel in question this has proved a valuable means of locating losses, and has enabled important improvements to be made.

* See previous reference.

Figure 4 shows the arrangements adopted for making these water measurements.

To measure the main condensate the air pump discharged through a water meter to a temporary drain tank from which one of the main feed pumps pumped it up into the measuring tanks. The measured water was drained away to the feed pump float tank from which it was pumped to the boiler by the other feed pump.

The auxiliary exhaust steam was condensed either in the surface feed heater or in the winch condenser and the drains from the feed heaters, winch condenser, oil separator, cabin heating, etc., were led to the auxiliary filter tank and from there through a water meter into the feed pump float tank.

When taking tank measurements of the auxiliary condensate, the main condensate was pumped through its water meter direct to the float tank and the auxiliary condensate after passing through its water meter was discharged to the temporary drain tank from which it was pumped up to the measuring tanks and drained down to the float tank to join the main condensate.

By leading both main and auxiliary condensate to the temporary drain tank, a measurement could be made of the total consumption.

It will be seen therefore that by this system of connections the main steam and the auxiliary steam were separately measured all the time by their water meters, and a tank measurement could be made of either or of both at any time.

It is only such measurements that can give the required information. Measurements of the consumption of the auxiliaries in port can only be made under artificial conditions, and it is difficult to make these imitate the exact conditions when on service. At the same time it must be recognised the auxiliary consumption per S.H.P. on one vessel under service conditions may not apply to another, and it is therefore necessary to make a careful analysis of the figures.

Using as a guide the results of makers' trials, from which can be acertained the consumption in pounds of steam per hour per A.H.P. or W.H.P. of each auxiliary engine, an attempt has been made in Table I. to do this for the vessel described by Mr. Potts.

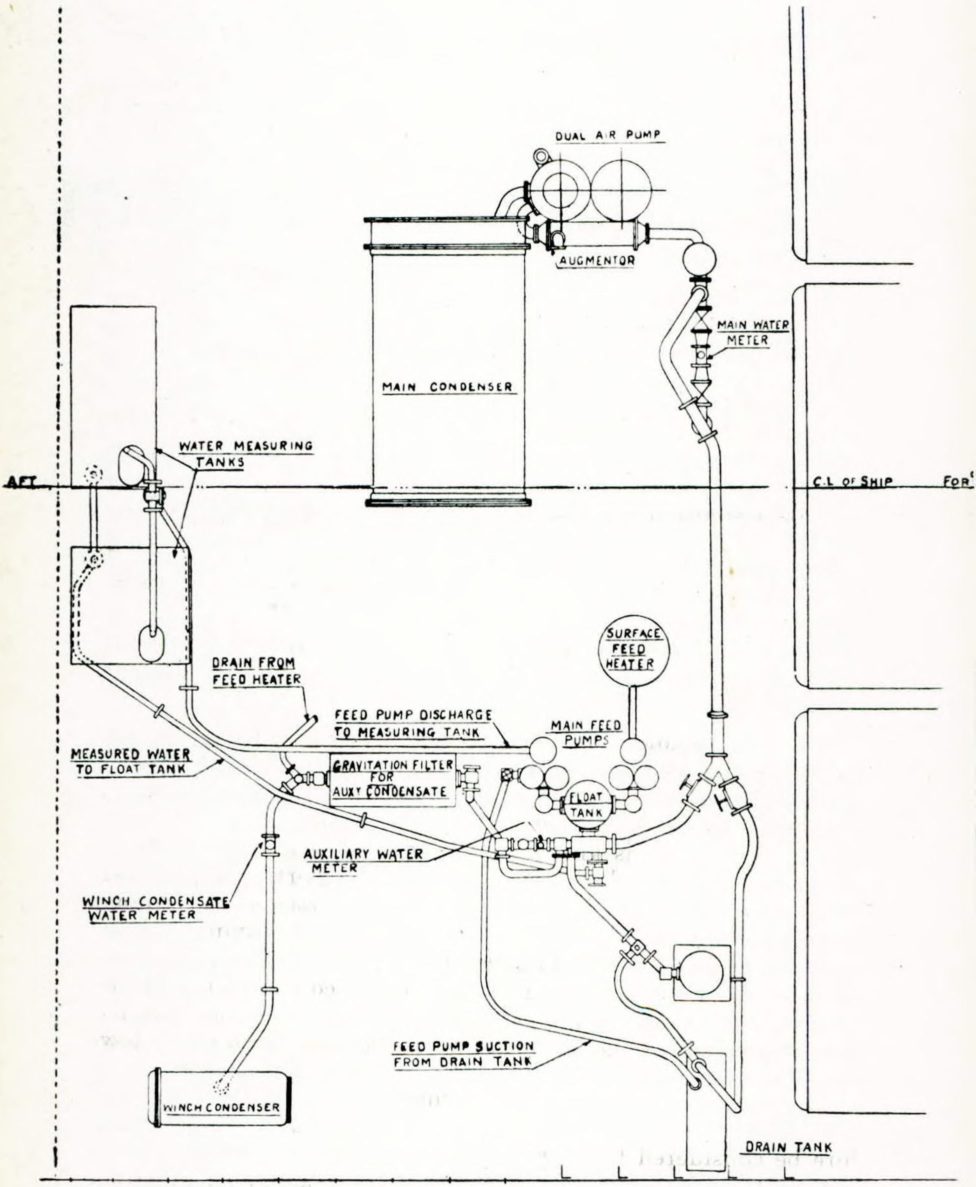


Fig. 4.—Plan View of Water Measuring Tanks and Pipes.

Table 1.—B.H.P. and steam consumption of auxiliary machinery for a geared turbine cargo steamer of 3,230 S.H.P.

	Duty.	Water H.P. or Air H.P.	B.H.P.	Estimated consumption lbs. per hour.
Air pump... ...	29,000 lbs./hr. condensate ...	—	5	350
Ejector		—	—	150
Circ-pump ...	2,700 galls./min. at 15ft. head ...	12·4	18	882
Feed pump ...	32,600 lbs./hr. feed 200 lbs. b.p. ...	7·5	9	540
Fans	20,000 c.ft./min. at 2″ W.G. ...	6·4	11	580
Oil Pump... ...	6,500 galls./hr. at 50 lbs. ...	3·8	4·5	330
*Steering Engine ...		—	—	450
Electric Light ...	2¼ K.W.	—	3·25	135
				3415

*The consumption of the steering engine is ascertained from measurements made with the small meter on the winch condenser condensate, referred to above.

As a confirmation of the general accuracy of this estimate, the total consumption for these auxiliaries ascertained by water meter as described above was 3,450 lbs. per hour.

The auxiliaries were supplied with steam at 100 lbs. pressure, 100°F. superheat and exhausted against a back pressure of 10 lbs. gauge.

When the whole of the auxiliary exhaust steam can be condensed in the feed heater, it is possible to estimate the amount of the former by the rise in temperature of the feed water in passage through the heater, provided of course that the quantity of feed water is known. Where neither measuring tanks nor meters are fitted, this can always be ascertained approximately by means of an integrating counter on the feed pump strokes. Such an estimate of the auxiliary consumption however has to assume a value for the total heat per pound in the exhaust steam, which theoretically should correspond with the heat in the steam supplied to the auxiliary engines less the heat equivalent of the output of these engines, with due allowance for radiation and mechanical losses, but actually where measurements have been made is found to be considerably less, and of somewhat uncertain value. This method cannot therefore be considered to afford more than a rough estimate.

In twin screw vessels where tanks or water meter are provided for the separate measurements of the condensate on each side, a good determination can be made by exhausting all the auxiliary steam into one condenser for the first half of the trial, and into the other for the second half. This method is frequently adopted in naval vessels.

Section 5.

On the same basis as in Table I., a summary has been prepared of the estimated consumptions for the auxiliary plant of a 5,000 S.H.P. installation with high efficiency turbines

Four different methods of driving the auxiliaries have been considered :—

1. Entirely by steam.

2. By electric motors, with current supplied from turbo-generators.

3. By electric motors, with current supplied from Diesel-generators.

4. Mechanically from the main engines, with the provision of suitable " standby's."

This summary is given in Table II.

With a boiler pressure of 500 lbs. per square inch, superheat to a temperature of 700°F. and a condenser vacuum of 29 inches of mercury, the steam consumption of the main turbines is estimated at 7·2 lbs. per S.H.P. hour. The consumption and duties of the various auxiliaries have been based accordingly on a condensate of 36,000 lbs. per hour.

Auxiliary exhaust steam at a pressure of 10 lbs. above atmospheric is utilised for heating the feed water up to 215°F. Where the auxiliary steam is insufficient for this purpose, the additional steam required is taken from the L.P. turbine steam belt. The feed water is further heated to a temperature of 310°F. by steam withdrawn from the I.P. turbine at a pressure of 110 lbs. per square inch absolute.

In proposal (1) the steam consumption of the auxiliaries including the ejector steam, the make-up feed and the steam used for the evaporator is 8,960 lbs. per hour. Of this 1,500 lbs. is condensed in the evaporator coil, and 250 lbs. in the oil fuel heater, leaving 7,210 lbs. available for feed heating. To heat the remainder of the feed water from 70° to 215°F. requires 5,800 lbs. of steam, leaving 1,410 lbs. unutilised, which may either go to the winch condenser or be led to the low-pressure turbine.

TABLE II.

Summary of the Estimated Auxiliary Consumption

for a 5,000 S.H.P.High Efficiency Installation.

Auxiliary plant	Duty	Water H.P. or Air H.P.	B.H.P.	1. Steam driven Steam required lbs/hr.	2. Motor driven with Turbo generators. Steam required lbs/hr.	3. Motor driven with Diesel generators. 4. Driven mechanically from Main Engines. Steam required lbs/hr.
Air pump	36,000 lbs/hr.condensate.29" Vacuum 60° Sea.		7	450		
Air Ejector				200	200	200
Circulating pump (Compound Engine)	4,700 gallons per minute.15 ft.head	21.5	31	1200		
Main Boiler Feed pump	44,960 lbs/hr. 500 lbs/sq. inch pressure. 700° F.	26.5	31	1600		
Forced Draught Fans	25,000 cub.ft/min.at 3" W.G.	12	20	860		
Forced Lubrication pump	10,000 gallons/hr. 50 lbs/sq.in. pressure	6	7	450		
Oil Fuel pump	3,400 lbs.of oil/hr. 200 lbs/sq.in. pressure.		1	200		
Steering Engine	(30 B.H.P.Motor)		8	750		
Electric Light Engine (Compound)			10	500		
Bilge,Sanitary & General Service pumps			3.5	250		
Make-up Feed				1000	1000	900
Evaporator				1500	1500	1350
			118.5	8960	2700	2450
Steam to Turbo-generator	110 K.W. (at 45 lbs.per K.W.hour)				4950	
Total Auxiliary Consumption.				8960	7650	2450
Condensed in Evaporator Coil.				1500	1500	1350
Condensed in Oil fuel heater.				250	250	250
Available for Feed heating.				7210	5900	850

The total steam consumption for all purposes is therefore in this case 44,960 lbs. per hour, or 8·99 lbs. per S.H.P. hour.

With a feed water temperature of 215°F, 13·2 lbs. of steam at 500 lbs. per square inch and 700°F. can be generated for each lb. of oil consumed in the boiler furnace. This figure is based on a calorific value of 18,500 B.Th.U. per lb. and a boiler efficiency of 84%, which can be attained with efficient pre-heating of the furnace air.

On this basis a steam consumption for all purposes of 8·99 lbs. per S.H.P. hour corresponds to an oil fuel consumption of ·681 lbs. per S.H.P. hour.

By utilising, however, steam tapped off from the turbines to raise the feed temperature to 310°F, whilst slightly more steam is required, this is generated at a higher evaporative rate and the oil consumption per S.H.P. is reduced to ·667 lbs.

The total brake horse-power required for the auxiliary machinery as enumerated in Table II. is 118·5, and in proposals 2 and 3 this power is supplied by electric motors, absorbing with a reasonable allowance for motor and transmission losses, 110 K.W. of electric power.

In proposal 2 the 110 K.W. are supplied by turbo-generators taking steam at the same pressure and temperature as the main turbines, but exhausting to a back pressure of 10 lbs. above atmosphere. At a consumption of 45 lbs. per K.W. they require 4,950 lbs. of steam per hour.

With the same supply of steam as before for ejectors, make-up feed and evaporator, viz., 2,700 lbs. the total auxiliary consumption in this arrangement is therefore 7,650 lbs. per hour, giving a total consumption all purposes of 43,650 lbs. per hour, or 8·73 lbs. per S.H.P. hour.

In this second proposal with 1,500 lbs. per hour condensed in the evaporator coil, and 250 lbs. in the oil fuel heater, there remains 5,900 lbs. per hour of auxiliary exhaust steam which is sufficient to heat the feed water to 215°F.

The steam consumption of 8·73 lbs. per S.H.P. hour all purposes then corresponds to an oil fuel consumption of ·662 lbs. per S.H.P. hour, on the same basis of boiler efficiency, etc., which is further reduced to ·648 lbs. per S.H.P. hour by using tapped off steam to heat the feed water to 310°F.

In proposal 3, the 110 K.W. required for the motors is supplied by Diesel generators.

The additional steam for ejectors, make-up feed and evaporators is in this case 2,450 lbs. per hour with only 850 lbs. per hour available for feed heating. Since however in this case 4,950 lbs. per hour is required to heat the feed to 215°F., this 850 lbs. must be supplemented by 4,100 lbs. of steam tapped off from the low pressure turbine belt, at the expense of a reduction of the power developed in that turbine by 285 S.H.P.

At a consumption of ·75 lbs. of oil per K.W. the Diesel generators consume 82·5 lbs. of oil per hour, which at an evaporative rate of 13·2 lbs. per lb. of oil is equivalent to 1,090 lbs. steam per hour.

So that finally for this proposal 4,715 S.H.P. are obtained for a total equivalent consumption of 39,540 lbs. of steam for all purposes, or at the rate of 8·39 lbs. per S.H.P.

The corresponding oil consumption is ·635 lbs. per S.H.P. hour with feed temperature at 215°F, and ·62 lb. with a feed temperature of 310F. using steam tapped off from the turbines.

In proposal 4 the 118·5 B.H.P. required for the auxiliary machinery is assumed supplied mechanically from the main turbines. With allowance for mechanical losses, it has been assumed that the output of the main turbines will thereby be reduced 132 S.H.P. As in proposal 3, it will also be necessary to bleed 4,100 lbs. of steam from the L.P. turbine for feed heating, involving a loss as before of 285 S.H.P. So that under this arrangement we have as the cost of supplying the auxiliaries, steam consumption increased by 2,450 lbs. per hour and output reduced by 417 S.H.P. or a total consumption of 38,450 lbs. per hour for an output of 4,583 S.H.P., or 8·39 lbs. per S.H.P.

This is the same as for proposal 3, and the oil fuel consumed per S.H.P. is therefore also the same as for proposal 3.

The calculations leading to these results are given in tabular form in Table III.

Summarised they are as follows:—

For proposal 1, with steam driven auxiliaries, ·667 lbs. oil per S.H.P. hour;

For proposal 2, with motor driven auxiliaries and turbo generators, ·648;

For proposal 3, with motor driven auxiliaries and Diesel generators, and for proposal 4, with auxiliary machinery mechanically driven from the main engine ·62.

TABLE III

Evaluation of Oil Fuel Consumptions.
of 5000 S.H.P. Installation

Conditions.

Initial Pressure	500 lbs. per square inch (absolute)
Initial temperature	$700^{\circ}F$.
Condenser vacuum	29 inches mercury (Bar.30")
B.Th.U per lb of oil	18 500
Boiler efficiency	84%

		1. Steam driven Auxiliaries. A.	B.	2 Steam-electric Auxiliaries.	3. Diesel-electric Auxiliaries.	4. Auxiliaries driven from main Engines.
Turbine Steam	(lbs./hr)	36,000	36,000	36,000	36,000	36,000
Total steam for Auxiliaries	"	8,960	8,960	7,650	2,450	2,450
Available for feed-heating	"	7,210	7,210	5,900	850	850
Utilised for feed-heating	"	5,800	5,800	5,700	4,950	4,950
Utilised in L.P. turbine	(lbs./hr.)		1,410			
Increase of S.H.P.	~~(lbs./hr)~~		98			
Tapped off from L.P. turbine	(lbs./hr.)				4,100	4,100
Decrease of S.H.P.	~~(lbs./hr)~~				285	285
H.P. absorbed by Auxiliary Machinery in (4)						132
S.H.P. for propeller shaft		5,000	5,098	5,000	4,715	4,583
Total Steam	(lbs/hr)	44,960	44,960	43,650	38,450	38,450
Oil for Steam production	"	3,405	3,405	3,310	2,910	2,910
Oil for Diesel Generator	"				82.5	
Total Oil	"	3,405	3,405	3,310	2,992.5	2,910
Lbs. oil per S.H.P. hour	at 215°F feed temperature	.681	.668	.662	.635	.635
	at 310°F feed temperature	.667	.655	.646	.62	.62

It will be seen from this comparison that with steam-electric auxiliaries the total fuel consumption may be made 2·85% less than when they are steam driven, and with Diesel-electric or mechanically driven, 7·6% less.

In proposal 4 it has, for the sake of simplicity, been supposed that all the auxiliaries are driven from the main engines. This may not be considered desirable in the case of all of them, even with the provision of adequate stand-by units. The result, however, as regards fuel consumption being the same as when these auxiliaries are motor driven from Diesel generators, one can make it apply equally to any combination of the two systems, that is to say, with as many of the auxiliaries as is considered practicable driven mechanically from the main turbines, and the rest motor driven from Diesel generators.

It has been assumed in determining the amounts of the steam consumptions that the steam supply to the auxiliaries is at a pressure of 200 lbs. per square inch and saturated. If this steam is generated in a separate low pressure boiler it will absorb less heat per lb. than the steam generated in the main boilers at a pressure of 500 lbs. and 700°F. The oil consumptions have, however, all been evaluated on the assumption that all the steam is generated in the main boilers.

To provide additional low pressure boilers for the auxiliary machinery, with duplication for the sake of overhauling and cleaning in port, would entail considerable addition to the plant. Some such provision is, however, necessary for the supply of deck machinery for cargo handling, and for the supply of saturated or only slightly superheated steam to the engine room auxiliaries before the main machinery is under way.

An interesting method of overcoming this difficulty has been put forward by Messrs. Babcock and Wilcox. The steam required for auxiliary machinery is drawn from the main boilers and passed through an "attemperator" in which it is intimately mixed with cold feed water, evaporating the latter, and its temperature thereby reduced. Thereafter it can be reduced by reducing valves to any pressure that is desired.

This simple method appears to meet the practical requirements and is at the same time economical. For since some further steam is generated by the evaporation of feed water it will be seen that the steam required for the auxiliaries is obtained at a lower cost of heat per lb. than in the main boilers.

It will lead therefore to slightly lower figures for the total oil consumption than given in Table III.

Mr. A. Jobling: The author's paper seems to be very highly theoretical. I quite agree with him that no other method of generating power is equal to steam turbines when they are working under the stable conditions which obtain in ordinary power station practice, but with regard to marine requirements present practice inclines towards the Diesel engine or to retaining the reciprocating steam engine. We have yet to learn whether the turbine is going ahead and making the same progress as the Diesel engine, and why the turbine has ceased to be of such utility as it is supposed to be in marine practice. Perhaps it is because the conditions are not so stable and firm as in land work.

The Chairman: I am not quite clear as to one point; in Table III, columns A. and B, with steam driven auxiliaries, the author gives the total water consumption as 8·39 lbs. in each case, but the shaft horse-powers are different, and he arrives at the same oil fuel consumption. Is that correct?

The Author: That is quite correct. I will explain it later.

Mr. A. F. C. Timpson: A point occurs in connection with the question of gearing. The adoption of higher speed turbines necessarily involves a greater reduction to obtain an efficient propeller speed and therefore a smaller pinion is required, which is liable to cause trouble. We often see gearing being taken out, and the whole engine-room is dismantled. Reliability is of primary importance in a marine installation, and I question, therefore, whether the fitting of higher speed steam turbines, even if they give a higher efficiency, will be advantageous (beyond a certain limit, of course).

Then as regards tapping off steam, I think the author said that that gives a greater efficiency because you have more steam available for heating the feed water. It seems to me that if you draw from the total amount of energy of the initial steam supply, you no longer have the same energy available for power. Although by tapping off it gives you a higher feed water temperature you must lose it in the S.H.P.

The summary (in Table III) of oil consumptions in comparison with the various types of auxiliaries is of particular interest, namely:

With steam auxiliaries—·667 lbs. per S.H.P. hour.

With steam-electric auxiliaries (turbo-generator)—·648 lbs. per S.H.P. hour.

With Diesel-electric auxiliaries—·62 lbs. per S.H.P. hour.

showing a fairly considerable reduction (7·6%) in the case of Diesel-driven auxiliaries. That goes to show that the prime mover is giving a greater overall efficiency when Diesel-driven than with either of the steam driven auxiliaries, which is also borne out by results obtained from the auxiliaries in certain motorships. The field of the turbine is in the higher powers where so far the Diesel engine has been unable to compete successfully, although it is beginning to enter this field also.

A MEMBER: A point of interest not touched upon by the author is a comparison, as regards first cost, between this 5,000 S.H.P. turbine installation and a Diesel set. I think the fuel consumption of ·62 lbs. per S.H.P. hour compares unfavourably with that of the average Diesel engine: i.e., ·53 lbs. A ship fitted with the auxiliaries mentioned in the author's tables would be what one might call a high-class ship, presumably a passenger vessel, nothing like the type of vessel to which the Diesel engine has so far been confined. I would like the author to give similar comparisons for a small ship of, say, 2,000 H.P., and particularly to show how it would work out in the case of a double-reduction set.

Then there is the question of superheat. I have observed that in installations which went up to 700° on the H.P. turbine, there has been trouble due to the excessive thrust on the main bearing. I think it would be an advantage if the forward bearing were a separate casting altogether, and that it would get rid of that trouble.

MR. T. W. LONGMUIR: The author's figures are based on a boiler pressure of 500 lbs. per sq. in. Have we any marine boilers working at this pressure to-day? As regards the fuel question, I think it is generally admitted that oil is most economically used in Diesel engines, and that the object of developing high-pressure turbines is solely to enable us to utilise our coal resources. It would be interesting, therefore, if the author could give similar figures based on coal as fuel.

I notice that in order to get the highest efficiency the feed water temperature was raised to 310° F. Where was the steam taken from to do that? It could not have been taken from the low pressure turbine, and it is open to question whether it would be economical to take it from the I.P. turbine.

Mr. J. F. Smail: I would like to ask the author whether he knows of any instance of a boiler on a ship in service giving an efficiency of 84%.

The Chairman: Referring to the installation which the author showed on the screen, of the geared set of turbines with three turbines working the one shaft, is that the suggested solution of the problem for all powers, or does he not think it would be better to increase the number of turbines with the power? It is assumed that for the medium powers you would get nearly the same efficiency with two turbines as with three or more.

I wonder also whether the author could give us particulars of any form of preheating which he could recommend for a marine installation. It has seemed to me a difficult problem to fit on board a ship a fairly simple and efficient preheating apparatus without considerable complication in the way of arrangement.

I would also like to know whether the author could let us know the final funnel temperatures for the installation he has been quoting.

The Author's Reply: Mr. Jobling seems to be unaware of the history of the solid achievements of the turbine in marine propulsion, being more impressed with the progress of the Diesel Engine. The past record of the turbine is, however, so familiar as to be almost commonplace, whilst the Diesel engine has still the glamour of novelty.

The enormous output of marine turbines, and its general adoption in the World's Navies and in the great liners, speak for themselves. As regards new achievements, reference may be made to three recent steamers for the Orient Line, which have shown great economy in fuel consumption. The first of these the *Orama,* with a three turbine arrangement at ordinary pressure and temperature and single reduction gearing gave a record in fuel consumption of ·785 lbs. of oil per S.H.P. The order for a further steamer of the same type has recently been placed with Messrs. Vickers, the builders of the *Orama.* A similarly good performance has just been recorded in the case of the Italian Liner *Conte Biancamano,* built by Messrs. W. Beardmore and Co., viz., ·77 tons of oil per S.H.P.

As regards further improvement in efficiency, an advance in this direction may be expected in the future by the use of high temperatures and pressures. A turbine installation is at present under construction for a Clyde steamer with a boiler pressure of 550 lbs. and a temperature of 750° F., which it is hoped will demonstrate the practicability of improvements in this direction and a considerable advance in efficiency.

In reply to the Chairman's questions with regard to the columns 3 and 4 of Table III., the object of the analysis is to determine the true cost of driving the auxiliaries. In case 3 with Diesel-Electric Auxiliaries the cost of driving the auxiliaries is represented by the consumption of a certain amount of fuel, viz., 82·5 lbs. of oil for the Diesel Generator. In case 4 with auxiliaries driving from the main engine, the cost of driving them is on the other hand represented by a reduction in the power of the main engines. That is why there is a difference in S.H.P. between the two cases, but at the same time there is a corresponding difference in the total oil consumption, and we arrive eventually at the same value for the consumption rate.

With regard to the use of a three turbine arrangement for large powers, I am not quite sure that one would be right in saying that a three turbine arrangement would show a greater advantage for high powers than for low powers. A three turbine arrangement enables one to have a more efficient installation and a high-pressure turbine of small diameter and high revolutions will probably show a greater advantage in a small power installation than in a large one. With a single reduction and three pinions grouped around one wheel, there will be a considerable saving in weight, particularly in the gearing, and this is an advantage which may be more pronounced in the case of large powers.

As regards preheating the only way in which the effect of preheating is included in the comparisons made in the paper is that it is assumed that, with preheating adopted, there will be a higher boiler efficiency which has been taken in the paper at 84%. This figure, however, does not affect the comparison as it has been taken the same for all cases.

I have seen efficiency figures of a marine boiler plant from actual measurements on service as high as 82% without any provision for air heating, beyond the ordinary heater of a Howden's forced draught system, so that to expect to obtain 84% with efficient air preheaters is quite a conservative assumption. The leading boiler-makers are quite prepared to supply preheaters and give efficiencies such as I have mentioned.

I cannot say definitely what the funnel temperature would be in the installation referred to, but presumably it will be about

450° F. With the arrangement shewn in Fig. 3 the temperature ought to be further reduced by a considerable amount, and that is why one should anticipate with such an arrangement a still higher boiler efficiency. It should be borne in mind that for every 50° reduction in the temperature of the funnel gases, there is an improvement of at least 2% in boiler efficiency.

Mr. Timpson suggested that there was some difficulty in adopting a high revolution turbine owing to its necessitating a smaller pinion. It will mean either a smaller pinion or a larger wheel. There will be a limit of course in this direction, but we have not reached it yet, and so far there is no difficulty at all in obtaining the higher revolutions required for the high-pressure turbines, especially if double reduction be adopted.

Mr. Timpson also questions the advantage of tapping off steam from the turbine for heating the feed water. The feed water cannot be heated to 310° F. by auxiliary exhaust steam, unless the back pressure on the auxiliaries is considerably increased, because this temperature depends upon the temperature at which the auxiliary steam can be condensed in the feed heater. An increase of back pressure on the auxiliaries would, however, increase their consumption and probably make the overall result worse. It is usual to exhaust at about 10 lbs. above atmosphere and at that pressure the exhaust steam can be condensed in the heater at slightly over 200°. As regards the utility of tapping off steam from the turbine to heat the feed water, the feed water has to be heated in any case, and the heat is ultimately derived from the same source, viz., the boiler, but when heating by steam tapped off from the turbine, the required amount of heat is first of all put into the steam in the boiler and then made to do some work in the turbine before being passed on to the feed water.

In reply to a member, as regards the comparison of Diesel Engines with Turbine Installations, this question was dealt with in the paper, to which I have referred, read by Sir John Biles at the meeting of the Institution of Naval Architects last year. It is necessary to take into account the first cost of the engine as well as the figure for fuel consumption per S.H.P. and taking into consideration the larger first cost of the Diesel engine it is held that for such powers as I have considered, viz., for 5,000 S.H.P. and upwards, and with the new proposals for ensuring high efficiency the geared turbine gives a more favourable result.

It must be remembered also that with a steam installation, coal can be used for fuel instead of oil, and this gives the steam turbine installation on the lines indicated an advantage over the Diesel engine at even smaller powers, probably down to the 2,000 S.H.P. referred to by a member. It should be pointed out, however, that the object of the paper is not to put forward figures of consumption for comparison with Diesel engines, but to bring out the comparison between the different methods of driving the auxiliary machinery.

In reply to Mr. Longmuir a comparison similar to that in the paper made on the assumption of the use of coal as fuel instead of oil would give practically the same results as regards respective advantages of the different systems of driving the auxiliary machinery. The figures need only be increased in the proportion of the values of the fuels. The steam required to raise the feed water to 310° F. would be tapped off at the exhaust end of the high-pressure turbine, or at an early stage in the intermediate-pressure turbine, as stated in the paper, at a pressure of about 110 lbs. absolute.

Mr. J. Clark: I have much pleasure in proposing a hearty vote of thanks to the author. I hope he is not disappointed with the small discussion, but it is very difficult to criticise the paper constructively. Many of us may have a little doubt on certain points, for instance, the question as to the 84% efficiency.

Mr. T. R. Alexander: I have much pleasure in seconding this vote of thanks to the author. This interesting paper is particularly useful in showing the possible improvement in efficiency of steam plant. The race for economy between steam driven and oil driven ships is not yet over, and bearing in mind the experimental work now in hand and the possibilities of existing apparatus, there is reason to believe the efficiency of steam plant will be substantially increased in the near future. The author quotes 84% as the boiler efficiency of a modern plant, which is decidedly conservative, for it is now quite practicable to obtain a funnel temperature as low as 200° F. with the aid of economisers and preheaters.

The installation of such apparatus in existing ships would prove a financial economy in many instances. We shall look forward to the results of the experimental plant in the ship mentioned by the author and share his confidence in them justifying his figures.

The AUTHOR: I thank you for the kind way in which you have received the paper, and should like just to add that my object when preparing it was to consider as impartially as possible the different methods of driving the auxiliary machinery for the purpose of selecting which ever proved to be the best. The figures have been most carefully sifted, and I think it will be found that they give a fairly true presentation of the comparative values.

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The Principles and Practice of Automatic Steering.

BY F. S. CLIFFORD,

READ

Tuesday, February 23, *at* 6.30 *p.m.*

CHAIRMAN: MR. F. M. TIMPSON.

INTRODUCTION.—There are few sea-going engineers who have not at some time or other had occasion to remark that so and so was at the wheel. Behind such comment lay a long story associated with the irregularities of the magnetic compass and the inequalities of different helmsmen.

Such is the raison d'être for automatic steering. But before proceeding to describe the principles underlying the mechanical control of the direction of a ship at sea, it is necessary to dispel the erroneous impression, which sometimes exists, that the art of steering requires some mysterious power of intuition, which, of course, cannot be possessed by a machine.

On analysis it will be found that this alleged anticipatory ability is in fact nothing more than an estimation of the sluggishness or liveliness of the magnetic compass card in relation to the actual change of direction of the ship's head.

It is for this reason that the human helmsman keeps one eye on the compass and the other on some distant object ahead or nearly ahead. By adhering to that practice he is able to judge approximately the time lag, and extent of oscillation of the magnetic compass card. This serves as a guide as to when and how much helm is to be applied for an assumed movement, as apart from an apparent change of heading indicated by the compass.

If that be appreciated, then it follows that since a machine cannot be expected to differentiate between the apparent and real movement of a ship's head, it will be realised that it is impossible to devise an automatic and mechanical contrivance which will operate satisfactorily in conjunction with a magnetic compass.

Therefore, the first essential to automatic steering is a compass which is capable of giving immediate and consistent indications of the slighest tendency of the ship to deviate from any desired course.

These requirements are to be found only in the gyro compass, which is not dependent on the varying forces of the earth's magnetism, and is unaffected by the iron and steel in the vicinity of the bridge, or by the movements of the ship in a seaway. It has, moreover, a directive force many times that of the magnetic compass and the design is such that all oscillation of the compass card is definitely eliminated.

The Relation between the Gyro Compass and Automatic Steering Apparatus.—Whilst it is not necessary to give an account of the whys and wherefores underlying the principles of the gyro compass in order to give a descriptoin of an automatic pilot, yet it is essential to deal briefly with the relationship existing between them.

Fig. 1 shows the gyro compass, which consists in the main of three elements:—

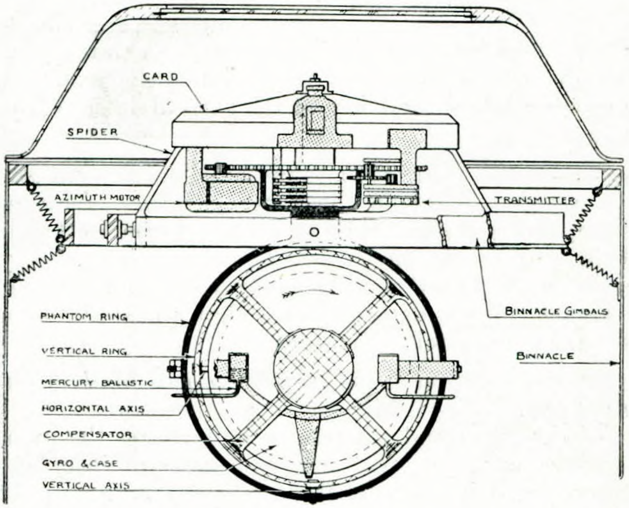
Firstly, that containing the gyroscope and the system of control which causes the axle of the wheel to seek and maintain the direction of the geographical pole.

Secondly, an outer element carrying the compass card, which by a simple electrical follow-up system, enables the north point of the card to be kept in precisely the same vertical plane as the axle of the gyroscope, and

Thirdly, a fixed supporting frame fitted with a ring concentric with the compass card and carrying the lubber line.

The Repeater System.—This principle of construction permits of an arrangement, whereby a gear wheel on the outer follow-up member engages with a pinion and drives the brush carriage of a commutator type transmitter which is attached to the fixed frame.

By those means, any relative movement between the compass card and the lubber line can be communicated electrically to any desired position. Thus the direction of the true north pole can be reproduced in a manner similar to that of an electric master clock, situated in the chart room and operating repeater time dials in the engine room and passengers' quarters.



NORTH ELEVATION.

Fig 1.—Master Gyro Compass.

These auxiliaries are known as repeater compasses and each unit consists of a small step-by-step motor which drives a compass card through a train of gears; the reduction being 180 to 1.

One such repeater motor forms an essential part of an automatic steering apparatus, and is shown at the top left-hand corner of Fig. 2, while to the right will be seen the transmitter on the master compass.

As will be observed from the connections, this motor has six poles, which are wound in pairs.

The transmitter is so arranged that it first energises one pair of opposite poles in the repeater motor, but owing to the brush carriage being staggered it follows that the second step of the transmitter will energise the next pair of poles, during which time the first pair remain energised.

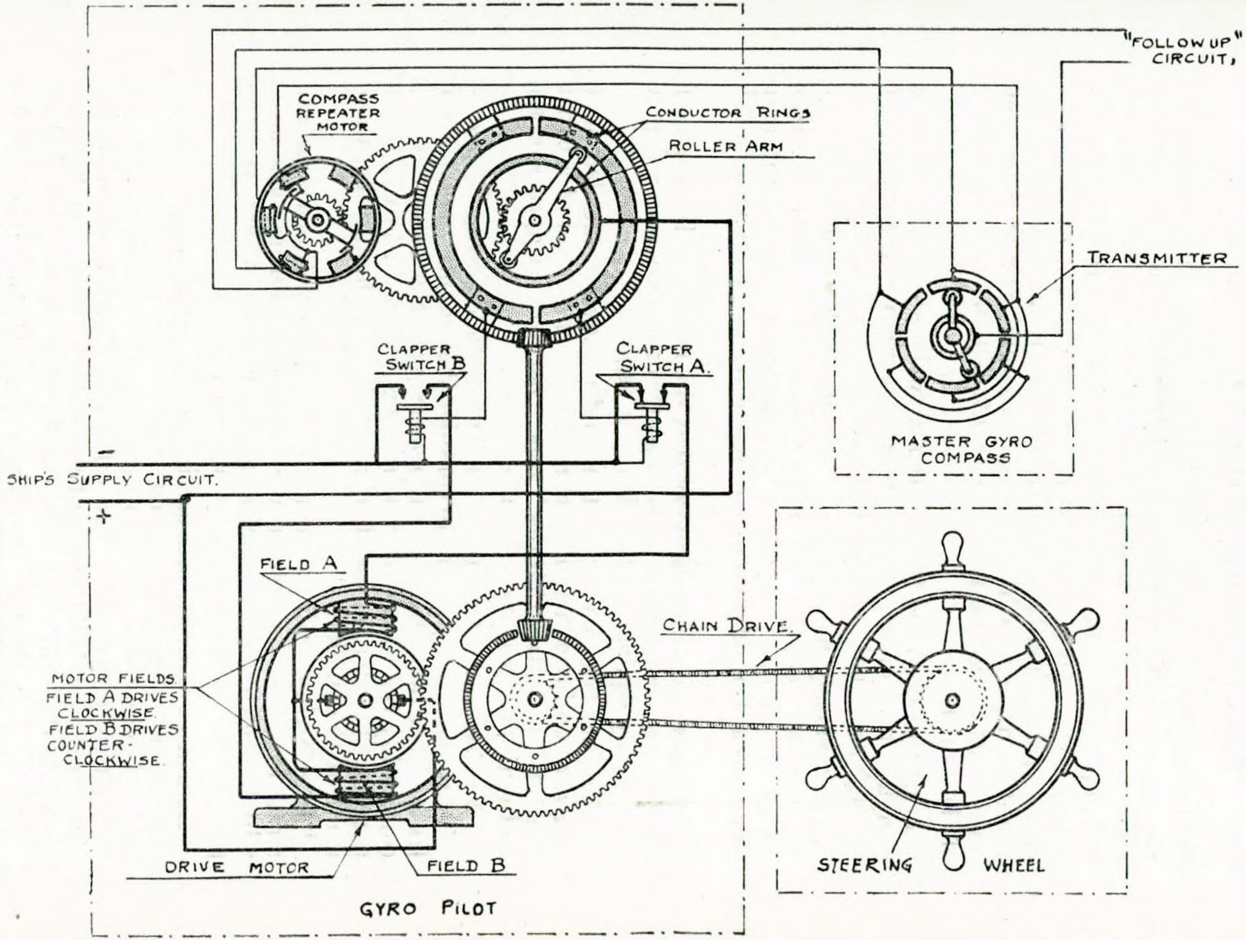


Fig 2.—Fundamental Elements of Automatic Steering Apparatus.

The third step will be such that the second pair of poles in the repeater motor remain energised while the original pair become de-energised, and so on.

From this it follows that the soft iron armature of the repeater motor will take up a position firstly in line with the first pair of poles, then lying evenly between two pairs of poles, followed by a position in line with the second pair of poles; the continuous procedure resulting eventually in a complete turn of the armature.

It will be observed that there are twelve definite steps for a complete turn of the armature, each representing a movement through arc equal to thirty degrees.

As previously mentioned the spindle of the armature drives the compass card through a gear reduction of 180 to 1, from which it follows that the actual movement of the repeater compass card in relation to one step of the armature will be 10° of arc.

Therefore, it is correct to say that the readings of the master compass are transmitted to the repeater compasses with a degree of accuracy equivalent to 1/6th of a degree.

What has been said up to the present may be regarded more or less as an introduction to our subject. For want of a better word it may be said that the "link" between the gyro compass and gyro pilot has been described.

The Essential Elements of an Automatic Steering Device.—We are now in a position to consider the manner in which the transmitted indications of the master gyro can be utilised for controlling the telemotor steering gear, which in turn actuates the throttle valve on the steering engine and finally the movement of the rudder.

On referring again to the same, Fig. 2, which is a diagrammatic sketch of an elementary automatic steering system—it will be seen that the compass repeater motor drives, through gearing, a contact making arrangement called the roller arm.

As will be seen, the arm carried at its extremities two carbon rollers, one of which runs on the inside of a conductor ring which is divided so as to form two half circles with air gaps diametrically opposed. The other roller, at the end of the short arm, runs inside a complete conductor ring, which is connected to the ship's electrical supply.

Further examination of the diagram will show that one-half of the split conductor ring is connected to the solenoid of a clapper switch "A" the other to the opposite clapper switch " B." These switches control the steering, stopping and direction of rotation of the " drive motor " is of the ordinary series wound D.C. type.

The drive motor, necessary gearing, and a roller chain, control the rotation of the steering wheel, which of course, actuates the telemotor system in the customary manner.

It is important to observe further, that the drive motor gearing also operates a vertical shaft which drives a bevel wheel, to which both the conductor rings are secured.

Principles of Operation.—In order to follow the operation of the mechanism it is well to reiterate that the three major units of the system consist of the master gyro compass, shown on the diagram by the transmitter, the gyro pilot and the steering wheel, which for the sake of explanation may be regarded as the rudder.

As a starting point we will consider that the vessel is steady on her course with the helm amidships. When those conditions prevail the air gap of the split conductor ring is in a vertical position and the roller contact is directly over it. Consequently, the circuit to the drive motor is incomplete and nothing happens.

Immediately the ship's head moves, the relative positions of her fore and aft line and the gyro axle alter. The result is that the " follow-up " system of the master compass causes the north point of the compass card to be kept in alignment with the gyro axle, although the relation between it and the lubber line changes. This actuates the brush carriage of the transmitter which controls the movements of all the repeater compasses and the repeater motor within the gyro pilot.

The impulses thus communicated to the repeater motor cause the armature to take up a fresh position and in doing so, the roller contact is driven from its normal vertical position to a position indicated in the diagram. Under these conditions, current is supplied from the starboard half of the conductor ring, and closes clapper switch "A," which completes the circuit to the drive motor through field "A," and results in the steering wheel being turned, and eventually produces rudder movement.

It will be observed that immediately the drive motor comes into operation to move the rudder, there is also a movement of the split conductor ring in such a direction that the gap chases the roller arm.

As soon as the ship responds to the application of the rudder, and steadies, the roller contact remains stationary, since there is no movement of the transmitter, but there will still be a tendency towards further rudder movement, until the movement of the conductor ring has reached a position so as to place the air gap over the contact roller. The circuit to the drive motor will then be broken and rudder movement cease.

At this stage of the evolution, the action of the rudder will commence to cause the ship to return to her course. This change of direction will be indicated by the compass, and a corresponding movement of the repeater motor will take place—this time in the opposite direction—and the roller arm will be carried to the other side of the split conductor ring.

In this case the circuit to the drive motor will be closed by the operation of clapper switch " B " and the motor will rotate in the opposite direction and apply a counteracting rudder movement. Once again the operation of the drive motor will produce a movement of the split conductor ring—only in the opposite direction—and the gap will chase the roller contact and eventually catch it up and break the circuit to the drive motor.

This procedure will be repeated until the ship is again steady on her course when the roller contact will be vertical and over the gap of the split conductor ring.

As mentioned before, the illustration gives only the simplest elements of an automatic steering apparatus, and if the mechanism was put on board in this simple form it would be found that a constant yaw on each side of her course would result.

The apparatus, as so far described—merely satisfies the two essential requirements, namely, to detect the immediate tendency to yaw and to apply instantly such movement of the rudder as will cause the vessel to return towards her course.

The Need of Flexibility.—Like an individual, every vessel has her own characteristics, and this applies particularly to her steering qualities. One ship may require a five degree rudder movement to counteract for a small initial deviation from course, while another may need only two degrees of rudder for the same amount of yaw. And then again, draught, trim and weather enter largely into the steering characteristics of all ships, so that in order to deal with the varying conditions which may be met with in different types of vessels it is necessary that any automatic steering apparatus must be of an exceedingly flexible nature.

The factors which have to be cared for may be summarised as follows:—

(1) A natural period of yaw as apart from a real deviation from course.

(2) Lost motion which may exist in the telemotor system and linkage in the steering gear.

(3) Rate and amount of rudder movement for the initial one degree alteration from course as required by any particular vessel.

The Complete Automatic Pilot.—We will now refer to Fig. 3 and see how these varying conditions are worked out in practice. It will be noticed that this diagram embodies the elements shown in the preceding one, and in addition it includes the necessary refinements to give effect to the requirements of any type of ship.

The repeater motor, it will be noticed, drives the contact arm through differential gearing, but the reason for this will be dealt with later.

The Weather Adjustment.—Considering the first of the three factors, it must be pointed out that the spindle carrying the roller arm is free to rotate until such time as a wedged-shaped pin—called the " weather adjusting knob "—situated on the gear wheel at the rear, is engaged. Thus, if this wedge is " two blocks " then the least movement of the repeater motor will result in an immediate movement of the roller arm. On the other hand, should the wedge be partially withdrawn, there will exist a certain amount of lost motion, which will enable the ship's head to yaw to an extent, depending upon the amount of slack, without any corresponding movement of the roller arm.

This is known as the " weather adjustment." In a smooth sea it is generally found best to eliminate this lost motion, and so allow the ship to get " helm " as soon as possible. During heavy weather it is advantageous to open the weather adjustment sufficiently far to allow the vessel to pursue her normal yaw in the prevailing sea, and so prevent continuous hunting of the steering gear.

The Telemotor Adjustment.—We come now to the second factor. It is obvious from reference to the diagram, that instead of the connection between the conductor ring and the drive motor being in the form of a vertical shaft, as shown in Fig. 2, there is employed a gear quadrant fitted with a similar wedge contrivance to that forming the " weather adjustment." This quadrant is mounted on the same shaft as a slotted lever, which in turn is connected by a driving pin to a second lever or arm. The base of this arm is attached to a gear wheel which forms one unit of a train of gears to the shaft of the drive motor.

For the moment it is convenient to ignore the fact that the lever can be shortened or lengthened.

We have seen already that as soon as the drive motor is energised, the movement is transmitted to the conductor ring, which chases the roller contact. It follows therefore, if the wedge on the gear quadrant is " two block " with the slotted lever, there is no lost motion between the motor and conductor rings. Under those conditions it is evident that the movement of the conductor ring starts and stops with the starting and stopping of the motor.

But if it be assumed that, say, three spokes slack motion in the steering wheel has to be taken up before the throttle valve on the steering engine opens, it would mean that the ship could deviate from her course to some extent without rudder movement being applied, although the steering wheel had turned.

That would make it possible for the ship to take a considerable sheer, and in order to allow for that condition, the " telemotor adjusting knob " enables lost motion to be put in between the gear quadrant and the slotted lever.

Thus it will be seen that if the wedge is partially withdrawn, the drive motor will over-run and take up the slack in the steering gear. In practice this adjustment is quickly ascertained by observation of the electric rudder indicator.

The Rudder Adjustment.—We now come to the third factor, which is, perhaps the most important—the adjustment which regulates the amount and speed of rudder movement for the initial deviation from the course.

A short while ago we referred briefly to the second lever or arm which carries a driving pin. It will be noticed that the lower end of this arm works in a guide, while a rack has been cut on its inside, the whole of which is capable of being raised and lowered by the manipulation of the " Rudder adjusting knob "—shown at the back.

The effect of raising this arm is to shorten the slotted lever, and *vice versa*. Consequently, it will be seen that a long lever will result in a relatively small movement in a given time—of the gear quadrant, and thence the conductor ring; on the other hand a shorter arm will give a greater movement of the conductor ring in the same period of time.

The rate of angular movement of the roller arm depends on the velocity of yaw of the vessel's head. On the other hand the rate at which the split conductor ring chases the roller arm depends on the length of the lever, and also the speed of rotation of the drive motor. The latter can be regulated by turning a snap switch, which has three positions, namely, slow, medium, fast.

Therefore, if the underwater lines of a ship, the nature of her stern, and the dimensions of the rudder, are such as to produce bad steering characteristics, it will probably mean that for a small departure from course, a relatively large amount of counteracting rudder, quickly applied, will be needed. This would necessitate turning the " rudder adjusting knob " in such a direction as to lengthen the slotted lever, and, may be, the best speed for the motor would be medium.

Taking the case of a vessel with a small co-efficient of fineness, a balanced rudder and high speed—a good steering ship—it is probable that a small rudder movement quickly applied would be found adequate to keep the ship as close to her course as possible. Under ordinary circumstances, the " rudder adjustment knob " would be turned so as to shorten the slotted lever and the speed of the drive motor would probably be best set at " fast."

By the very nature of things, it is not possible to lay down any definite rule with regard to the proper setting. A few watches at sea with the " rudder adjusting knob " in different positions will quickly reveal the general steering characteristics of the vessel. Subsequent changes of the adjustment, and alteration in the speed of the motor, to take care of varying weather conditions, should, with a little practice, be easily carried out.

Having described the reason for different adjustments and the methods employed for making same, it is necessary to mention that the procedure entails no anxiety for the officer-in-charge of the watch.

The telemotor adjustment remains practically constant providing the pressure of the hydraulic system is maintained.

The rudder adjustment should only require resetting when a considerable change of draught or trim has taken place, or, may be, when heavy weather is experienced. In the latter circumstance it may be found advantageous to reduce the motor speed.

The weather adjustment is needed, as a rule, only in heavy weather, and is turned sufficiently to prevent continuous hunting of the steering wheel and to allow for the normal yawing period of the ship.

The Pilot Wheel.—There remains but three further items which are entitled to some explanation. One is the pilot wheel. This is shown at the top of Fig. 3, and it will be observed that the wheel is capable of being moved to an " in " position and an " out " position.

Automatic Steering Position.—When the pilot wheel is in the " out " position, the point of its spindle is clear of the gear wheel having holes near its periphery. In that position there is nothing to obstruct the repeater motor driving the roller arm. This is called the automatic steering position.

Hand Steering Position.—When the pilot wheel is pushed to the " in " position, the point of its spindle is engaged in one of the holes of the gear wheel opposite to it, which has the effect of locking the repeater motor.

It is here that the differential comes in. Since the gear on the rod has also become engaged with another gear, any movement of the pilot wheel will result in direct control of the roller arm—expressed differently—hand steering is achieved in a simple and satisfactory manner.

Limit Switches.—Another point worthy of mention is the limit switch. This is shown clearly on the diagram. It can be set so that the cam breaks the circuit to the drive motor at any pre-determined rudder angle.

The switch is arranged in such a way that at the moment of opening it rings an alarm bell on the bridge, and when the ship responds to the action of the rudder the alarm ceases and the circuit to the motor is closed automatically.

Drive Motor Clutch.—An ordinary dog type clutch is provided for engaging and disengaging the gyro pilot from the steering wheel.

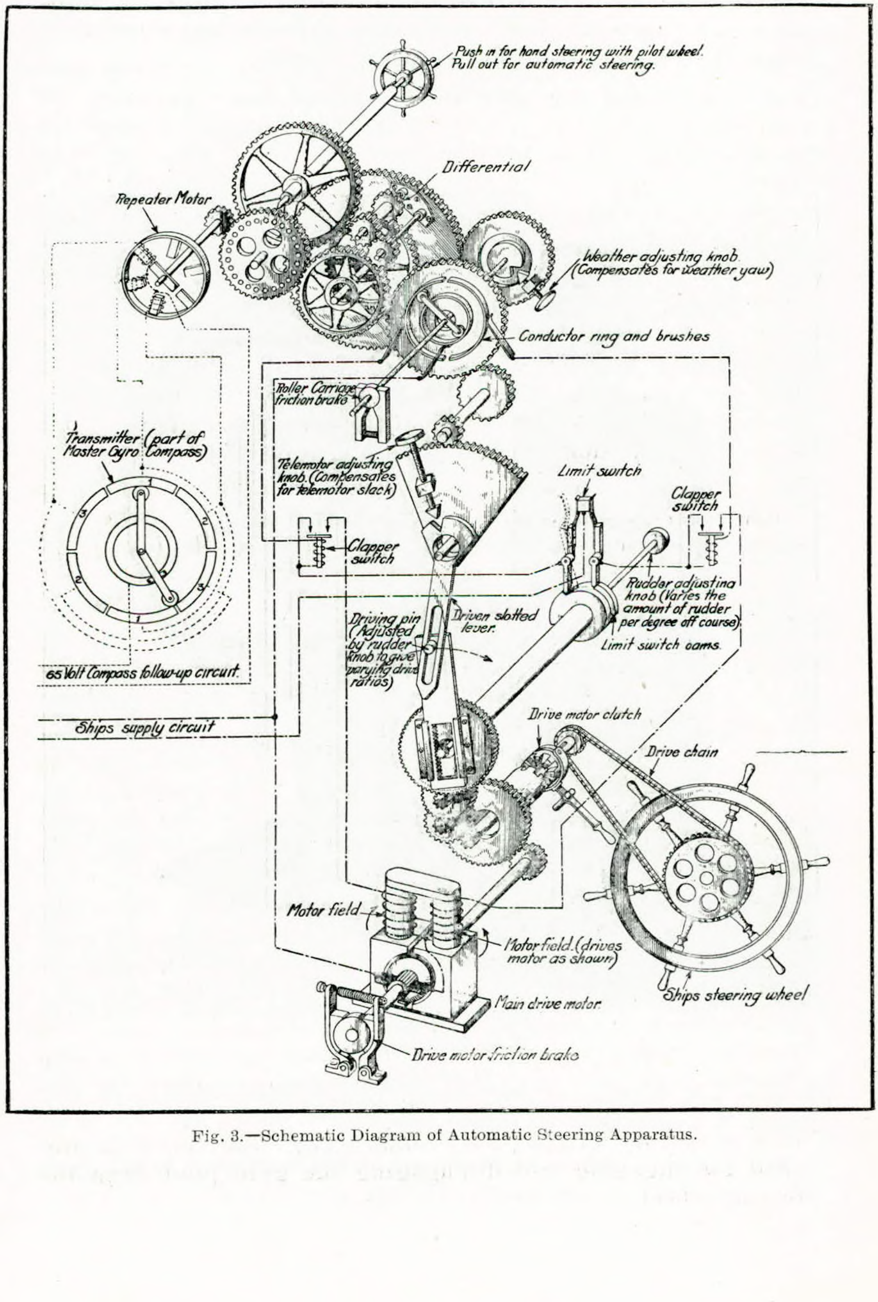


Fig. 3.—Schematic Diagram of Automatic Steering Apparatus.

Automatic Steering in Practice.—Figure 4 shows the automatic steering apparatus connected to the steering wheel of a ship. The various controls are clearly shown.

On the assumption that we are bound down channel, we will suppose that the Trinity pilot has been discharged off

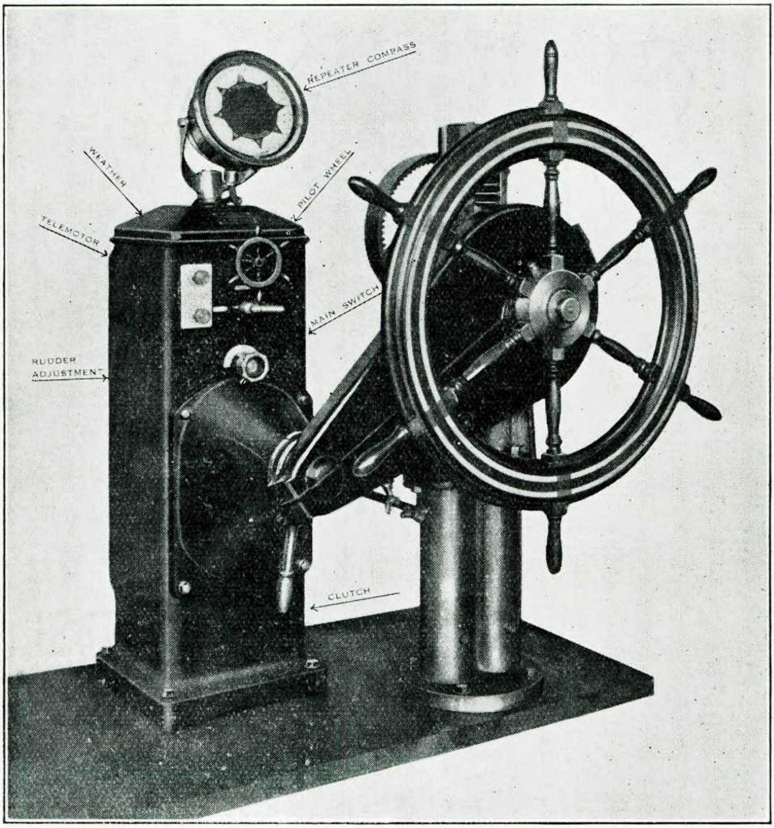


Fig. 4.—The Gyro Pilot.

Dover, and that the quartermaster has steadied the ship on her course to a position off Dungeness.

The known adjustments having already been put on the gyro pilot, the officer of the watch pulls the pilot wheel to the " out " or automatic steering position, sees that the helm is amidships, and then closes the clutch, which engages the apparatus with the steering wheel.

The vessel will now be kept on her course automatically and by a little attention to the graph made by the course recorder, combined with observation of the helm indicator, it will become an easy matter to make any minor modifications to the adjustments so that the ship will make the best possible course with a minimum rudder movement.

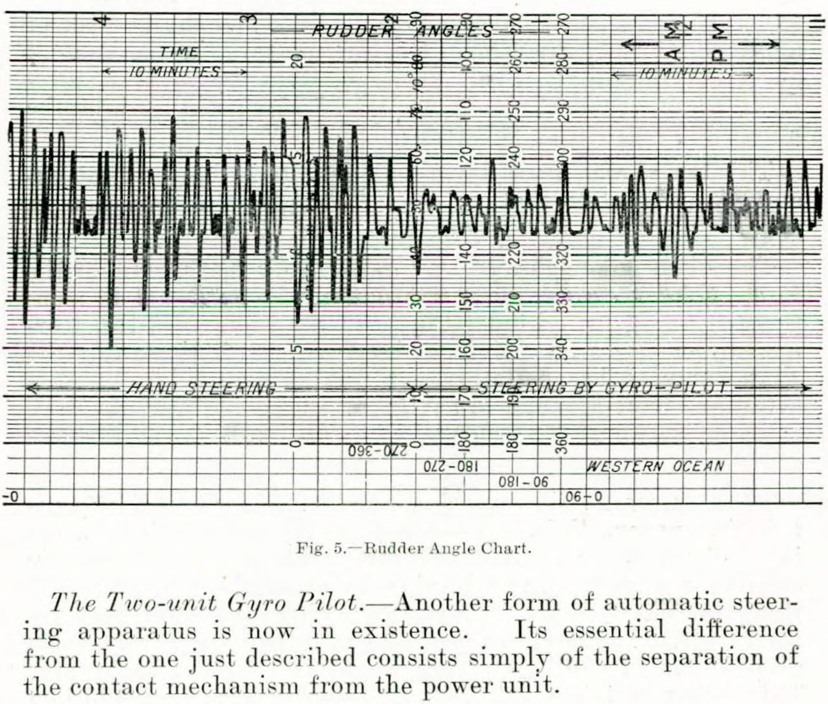


Fig. 5.—Rudder Angle Chart.

The Two-unit Gyro Pilot.—Another form of automatic steering apparatus is now in existence. Its essential difference from the one just described consists simply of the separation of the contact mechanism from the power unit.

The former is on the bridge and is in no way connected to the ship's steering wheel. It operates the power unit which is situated in the steering engine house, and, by a suitable arrangement, controls the throttle valve.

This type has a distinct advantage, inasmuch as all slack in the telemotor gear is eliminated, and also provides an entirely independent system of steering.

The Value of Automatic Steering.—The economical operation of a ship at sea is dependent on so many varying factors that it is quite impossible to state definitely the saving which automatic steering confers on a vessel which is equipped with the modern apparatus.

Figure 5 is a reproduction of a section of a graphic chart made by an automatic rudder angle recorder on board a steamer employed in the Western ocean trade.

An examination of this will show that when the vessel was being steered by hand, with the aid of a magnetic compass, the extent of rudder movement was very great and the number of applications very frequent. On the contrary in the case of automatic steering it is very noticeable that the angular movement of the rudder was immediately suppressed, while the number of movements was reduced.

This record was made during a gale. It is, however, no exaggeration to state that, as a general rule, the reduction in rudder movements is rarely ever less than 40%.

The extra power absorbed by unnecessary movements of the rudder, and the consequent retardation of speed—not to mention the saving brought about by less wear and tear of the steering engine—are a few points, which I suggest, indicate that the gyro compass has certainly contributed something towards better and more economical navigation.

The Chairman: We have to thank Mr. Clifford for a most interesting paper. We had a paper on the gyroscopic compass in October, 1913; also in October, 1914, but the automatic steering apparatus shown to-night is quite a new feature. I think the chart shown is very interesting; it brings back remarks often heard at sea years ago, to the effect that some graphic record of the steering would be of great assistance. This system certainly attains that desired object. I would like to ask the author whether this apparatus is actually in service.

The Author: Yes; there are about one hundred ships fitted with automatic steering apparatus. I think it may be interesting if I tell you that the machine is sufficiently flexible to enable the very same model that steers the *Berengaria* of 52,000 tons to steer the ex-Admiralty motor launch *Amo II*, owned by Mr. Ernest Guinness, of only 35 tons.

Mr. F. O. Beckett: Will the author kindly have the slide of Fig. 3 shown again, I would like to ask for a little further explanation of the solid link and plug; could he show us how it operates.

The Author: I think you refer to the "Rudder adjustment"; this regulates the angular amount and speed of movement of the rudder. The necessity of this feature will be evident if the underwater section of a fast passenger ship is compared with that of a bluff collier. One would require a quick and small movement, the other a larger and perhaps a slower movement. It is accomplished by lengthening or shortening the lever movement between the drive motor and the conductor or follow-up ring, the effect of which is to provide a means whereby the conductor ring may chase the roller contact either quickly or slowly, this adjustment is regulated by the movement of the driving pin up or down inside the slotted lever.

Mr. A. Jobling: Do you dispense with the quartermaster altogether or is it necessary to have him standing by.

The Author: That is a matter best decided by the captain of the ship. It will be appreciated that at first the whole procedure will be so entirely strange that caution and, may be, a little mistrust may be expected. That is only natural. Later, as confidence is gained, there is a lesser tendency towards having a quartermaster actually stationed close to the wheel, but rather to employ him at some job on the bridge. In fair weather runs there appears no need for the helmsman to be on the bridge, as the change over from the automatic to hand-steering is so simple and rapid that it could easily be accomplished by the officer of the watch.

Mr. Jobling: Mr. Clifford is to be congratulated on giving such a useful paper. I think this apparatus will save the chief engineer a good deal of anxiety regarding his bunkers, as it eliminates indifferent steering.

The Author: Yes; that is so, and there are other advantages to be gained. It frequently happens that very heavy seas are shipped for no other reason than that the helmsman is deceived by the magnetic compass and applies the helm the wrong way. When this occurs, it means that the ship's head is either made to fly up to windward or to fall off into the trough of the sea with a result that unnecessary water is shipped. There is also the human aspect: namely, that the helmsman is at his best for the first period of his trick at the wheel and whose efficiency becomes less and less as four or eight bells is approached.

Mr. Jobling: I suppose the ordinary compass deviation does not enter much into this.

The Author: There are no errors at all. Since the gyro compass is non-magnetic, it does not matter what masses of iron or steel may be near the apparatus; or you could place magnets all round it, but they would make no impression.

Mr. Jobling: Where does the gyro weight come in. And how do you adjust that for differences in the course.

The Author: So far as automatic steering is concerned, it is convenient to regard the apparatus as the muscle which turns the steering wheel, while the gyro compass, which is a separate unit, may be regarded as the brains of the complete equipment. The indications of the master compass are communicated to the automatic steering device by means of electrical impulses and nothing more. Thus the gyro compass itself is not interfered with when an alteration of course is required, which function is performed by moving the small wheel on the gyro pilot.

The Chairman: It is interesting to see the progress which is being made in these matters. I understand that without compasses of this class we could not navigate certain classes of vessels, submarines in particular. I believe that two battleships were placed at the disposal of the German naval authorities prior to 1914 for experiment in this problem.

I am sure I am voicing the feeling of the meeting, when I propose a very hearty vote of thanks to Mr. Clifford for his paper.

Mr. Clifford briefly acknowledged the vote of thanks and expressed readiness to answer any further question which may be sent to him in writing.

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Notes.

"North Eastern" Double Acting Four Stroke Diesel Engine for M.S. *Stentor*. (A. Holt & Co., Liverpool).—This engine, which is the first of a new type to be put into service, will propel the most powerful single screw motorship afloat. It is the result of four years experimental work carried out jointly by The North Eastern Marine Engineering Co., Ltd., Wallsend-on-Tyne, and Messrs. Werkspoor, Amsterdam, the leading particulars being as follows :—

6 Cylinders.

820 m/m (32¼ ins.) Bore.

1,500 m/m (59 ins.) Stroke.

4,500 B.H.P. in Service at 95 R.P.M.

The experimental engine at Wallsend is a unit of large size, the cylinder bore being 800 m/m (31½ ins.) and the stroke of piston 1,400 m/m (55 ins.) and has been running for the past three years, the experimental work has been very extensive, and includes four continuous runs of from 21 to 80 days duration, the engine having turned over 30 million revolutions during that period.

In the engine under review the usual accessibility of the piston for inspection and overhauling so well tried out in the North Eastern Single Acting Engine has been retained in the Double Acting Engine. Incidentally, this makes the inspection and gauging of the internal surfaces of cylinders a comparatively easy operation. The valves at both top and bottom of cylinder can be quickly and easily removed where necessary.

The cylinder heads are of Perlit Iron, and of the well known single acting design with fuel valve off the centre line, thus giving ample water space between the valve ports. The cylinder liner is separate from the head, the joint being just above the travel of the top piston ring, thus permitting of a new liner being fitted to the existing head. Studs and nuts at this joint are of stainless steel. The necessary valves for bottom end of cylinder are housed in a separate combustion chamber, which is bolted to the bottom cover with a ground joint. The bottom cover, combustion chamber and stuffing box are of Perlit Iron.

The piston rods are 11 ins. diameter, and of special alloy steel with a 2½ ins. hole up the centre for the passage of piston cooling water. A large flange is provided at the top end to which the piston is bolted, this being the only joint in the piston, and the connecting bolts are of nickel chrome steel.

The pistons are of Perlit Iron and carry 11 rings, and a special packing of N.E.M. design and manufacture is fitted to the piston rod stuffing boxes, which are separate from, and bolted to, bottom of cylinder cover, thus facilitating examination of the packing. A recess is provided in the piston between upper and lower groups of rings which communicates with a test valve connection in cylinder walls when crank is on bottom dead centre, the valve being opened at the correct moment by a cam. A connection from this valve to a pressure gauge shows whether any leakage is taking place past the piston rings. Fresh water is used in the pistons, a cooler being mounted on the engine column, and the water is conveyed to and from the pistons by means of heavy gauge telescopic pipes mounted to the astern guide shoes. The packing of these pipes has received special attention on the experimental engines, and a combination type fitted in a stuffing box having some degree of flexibility has been found to give entirely satisfactory results.

The engine framing comprising cast iron " A " columns has been designed on the same lines as the experimental engine, and also as the Single Acting Engines of the M.V. *Raby Castle*, which have proved so satisfactory in service.

The crankshaft is 21 ins. diameter, and built up on the "Unity" system of construction, and is perhaps the largest shaft so far built in this country.

The top halves of main bearings are held down by cast steel keeps supported by nuts on the main bolts, which are carried right through from top of cylinder beams to the under side of bedplate.

Each crosshead is guided by one ahead and two astern guides, there being sufficient space between the latter to allow the top end of the rod being swung outwards, and the whole of the main running gear is forced lubricated.

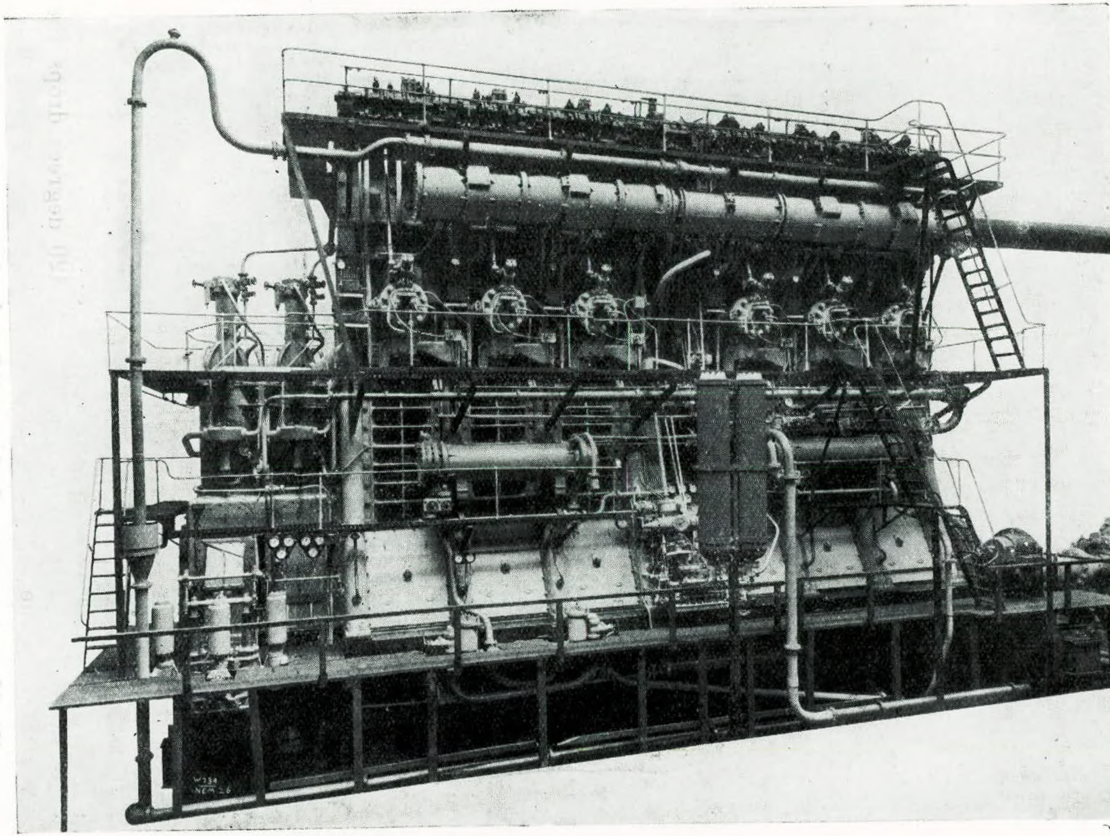
The engines are reversed by means of sliding the cam shaft. The top rocking levers are mounted on eccentrics on the reversing shaft, which carries a scroll-cam for sliding the cam shaft.

The operation is as follows:—

(1) Put starting shaft to stop position, in which position eccentrics and cams on this shaft lift the bottom valve levers clear of the cam shaft cams.

(2) Move reversing shaft from (say) ahead to astern, the first 120 degrees of this motion lifts the top valve levers by means of the scroll-cam, and the last 120 degrees drops the levers on to the top astern cams.

(3) Move starting shaft to "6 cylinders on Air," after which the sequence of operations will be as indicated later.



Internal Combustion Engine of the "Stentor," Double-acting, Four-stroke with six cylinders, 32¼in. diam. x 59in. stroke.

The reversing shaft is rotated by means of a rack and pinion, the pinion being cut on the shaft, and the rack driven direct by an air cylinder in conjunction with an oil damping cylinder.

The starting shaft is turned by means of a compressed air motor, and has 5 positions, as follows:—

1. Stop.
2. 6 Top Cylinders on Air.
3. 3 Top Cylinders on Air, 3 Top Cylinders fuel.
4. 6 Top Cylinders fuel, preheating on Bottom.
5. 6 Cylinders double acting.

In all positions of starting shaft except (5) the bottom exhaust valves are held open, and the bottom inlet valves are out of gear and shut.

The starting shaft actuates the main starting valves in the standard way, and also controls the fuel pumps and the blast air.

The engine is fitted with one fuel pump per cylinder of the double acting type, one end supplying the top of cylinder and the other supplying the bottom. Fuel supply is controlled by the suction valve lift, which is held open for a greater or less proportion of the stroke. An Aspinall Governor also controls the suction valves of the fuel pumps.

The cam shaft is driven by a pair of crank shafts, gear wheels being introduced to keep the length of coupling rods down to previous satisfactory practice.

A general idea of the engine will be obtained from the photograph reproduced.

AWARDS.

Lloyd's Register Scholarship.—After the examination papers were examined and the results tabulated, the full particulars were submitted to Lloyd's Register of Shipping, and discussed, when it was decided to call the three candidates who gained the highest marks for a further examination as to their personality and outlook. This was arranged for and carried into effect after which the following report was forwarded to the Secretary of Lloyd's Register of Shipping for further consideration and final decision: —

"In accordance with the view expressed after submitting the results of the Examination and the details as to the candidates who gained the three highest places, arrangements were made to have each of them interviewed by two Representatives from Lloyd's Register of Shipping and two Representatives from the Institute of Marine Engineers, together with the Honorary Secretary.

The candidates were interviewed on June 17th in the following order:

R. T. Gardiner, age 20, from Cork, where he has been serving his apprenticeship. Number of marks gained in all—649.

J. R. Morgan, age 22, from Barry, where he served his apprenticeship. Number of marks gained in all—597.

E. R. Hall, age 20, from Plaistow, London, E., where he is serving his apprenticeship. Number of marks gained in all—564.

The Committee of Representatives, after examining each one separately, came to the unanimous conclusion that the three were all good examples and well worthy of support and encouragement in their desire to progress in study and research, both in theory and practice.

Careful consideration was given to each case on its merits, and it was resolved to recommend that the Scholarship be awarded to R. T. Gardiner.

With further reference to J. R. Morgan, who has attempted the examination and gained second place on three occasions, 1924, 1925 and 1926, and would be over the age limit of 23 next year, a sympathetic view was taken and the Institute decided to grant £10 to Morgan to assist him in his study towards obtained the B.Sc. Degree.

With regard to E. R. Hall, he was encouraged to keep on studying and have another trial next year."

James Adamson,
Hon. Secretary.

Lloyd's Register of Shipping has decided that the Scholarship be awarded to R. T. Gardiner, who will enter upon his University Course on the opening of the Session.—J. A.

The following is from "Lloyd's List and Shipping Gazette," of February 10th. A copy of the Paper quoted is in the Reading Room:—

Future of Steam.—An important and valuable paper was read last night before the Institution of Engineers and Shipbuilders in Scotland by Sir James Kemnal, on "The Development of Increased Efficiency in Steam Application for Marine Purposes," from which we have extracted the following passages:—

Increased efficiency, both in land installations and on board ship, with increased economy in fuel, as well as the desire to make steam installations give the same calorific efficiency that is obtainable from the Diesel engine, is the origin of many improvements that have appeared in steam plant. These improvements are based mainly upon increases of pressure, feed temperature, and temperature of the superheat, and are restricted in the last case to the limit that the material of which the superheaters are made will stand.

The scientific foundations and advantages in connection with increased temperature and pressure have, of course, been known since the days of Carnot, Hirn, Rankine and others. Many years ago Perkins built marine machinery to work at a steam pressure of 1,500 lb. per square inch, but his attempts failed owing to the lack of mechanical facilities, and of the knowledge and machinery required for the construction of suitable boilers and engines.

Heat Content.—The gain due to higher steam pressure arises partly from the fact that the heat content per lb. of steam, while it increases slightly up to 350 lb. per square inch, commences then to diminish slowly, and, therefore, as the pressure is increased above 350 lb., no more heat, but theoretically slightly less, has to be transferred from the fuel to the water at the increased pressure. Consequently, with suitable arrangements of the turbine, greater utilisation of the steam can be obtained from the fuel at the higher pressures.

It should be observed at the outset that the efficiency of the boilers is not materially modified, but changes in design and construction have been made to enable higher pressures to be used, with which, per unit of steam, more work can be done by the machine. It is only in comparatively recent times that the construction of steam generators, suitable for these high pressures, has been studied and become practicable, and the results obtained have been entirely from land installations. The development of the application of high pressures has taken place in two directions:—

(1) In utilising pressures of 600 or 700 lb. per square inch in new turbines which exhaust at pressures of from 250 to 350 lb., and using this exhaust steam in existing plants.

(2) In specially constructing turbines to utilise high pressure throughout the whole range, by increasing the stages of expansion in the one machine and reheating.

Plant Abroad.—Of the former, the most prominent installation is at the Société d'Electricité de Flandre Langerbrugge Power Station, working at a pressure of 56 atmospheres (800 lb. per square inch). At this station the anticipated results have already been achieved, and it is expected that eventually a thermal efficiency of from 28 to 30 per cent. will be realised. This is not far, if at all, short of what is obtained with the Diesel engine, and has this advantage, that a very much cheaper fuel, oil or coal, can be used for generating steam.

Of installations of the second category referred to, the Philo Station of the Ohio Power Company and the Crawford Avenue Station of the Commonwealth Edison Company are the most promising practical examples. Each has a working steam pressure of 650 lb. per square inch, and a temperature of 750 deg. F. There are many other installations in America which will shortly prove striking examples of the increased economy due to high pressure.

For some time boilers have also been constructed to work at from 500 to 1,250 lb. steam pressure, mainly for testing valves, etc., notably at the Hancock Inspirator Works, the Consolidated Safety Valve Works, and Babcock and Wilcox's Works at Dumbarton.

In the trials carried out at the Philo Power Station, one kilowatt was generated at an expenditure of between 13,000 and 14,000 B.Th.U.'s, which, converted into shaft horse-power for marine purposes would be under 10,000 B.Th.U.'s, corresponding to a thermal efficiency of about 25 per cent.

In all these installations, Babcock & Wilcox boilers, superheaters, economisers, and reheaters are used, this type of boiler being the only one adopted on a commercial scale, and with which definite results are recorded. At present there are no large installations in England working at these high pressures, excepting the forerunner, which was designed by Merz & McLellan for the North Tees Power Station of the Newcastle-upon-Tyne Electric Supply Company, where for five years ten boilers have been working at 500 lb. pressure, and quite recently another eight boilers have been installed, and are now in use. I have seen no records from this installation, but it is understood that the gain in economy, due to the higher boiler pressure, is from $4\frac{1}{2}$ to 5 per cent., exclusive of the gain due to reheating and bleeding for feed-water heating.

In Germany the question of high pressures has been taken up with avidity. Over 100 boilers, having an aggregate heating surface of 68,000 square metres and of varying designs, are at present being constructed. There is also an interesting installation being carried out by Babcock & Wilcox at the Electric Power Station at Amsterdam, where the boilers are intended to work at 620 lb. pressure, with a superheat temperature of 795 deg. F., and to supply 156,800 lb. of steam per hour to a new turbine which exhausts at a steam pressure of 230 lb. This exhaust steam is resuperheated in the reheater integral with the boiler to 795 deg. F., and is then conveyed to the original low-pressure turbines. This arrangement is very similar to that of the Flanders installation, excepting that in the latter there is no reheating, but a high initial degree of superheat of 954 deg. F. Under this temperature, durability is at least an open question. The Amsterdam boilers are fitted with appliances for burning pulverised fuel, the installation of which was also carried out by the boilermakers.

Several other plants might be mentioned which also have reheaters, notably the Philo and Crawford Avenue plants, the North Tees plant, and a station working at 400 lb. pressure at Barking, designed by Merz & McLellan for the County of London Electric Supply Company.

In order to deal more effectively with the high temperature to which the steam is superheated, the superheaters are placed nearer the furnace zone than formerly. Nevertheless, the material at the present time on the market from which superheater tubes can be made places the probable limit of working temperature at about 750 deg. F.

Marine Work.—Recently the question of adopting high pressure in marine work has come to the front, and a Clyde steamer, at present being built in Dumbarton for the Turbine Steam Navigation Company, will be fitted with high-pressure boilers and turbines for a working pressure of 500 lb. per square inch. The boilers, in which lightness of weight and low first cost were the main considerations, are being constructed by Messrs. Yarrow & Co., and the results obtained from this innovation will be followed by marine engineers with great interest. In this case, in order to help the boilers, the condenser of the main engines is being made in two sections, so that one section can always be in use while the other is under repair. The boilers approximate more closely to the type fitted in destroyers, which is, perhaps, not the most suitable for general mercantile work.

Sir Charles Parsons asserts that with high pressure and superheat, turbine installations can, undoubtedly, be carried out in a practical manner to give the same thermal efficiency as the Diesel engine, and with lower running costs. The sectional design of the Babcock & Wilcox boiler has proved itself exceptionally adaptable for high pressures, and boilers of this design have recently been put forward for pressures of 1,500 lb. per square inch. The trials at the Edison Illuminating Station, Weymouth, with a pressure of 1,200 lb., are awaited with great interest. In these high-pressure installations, the greatest care is required in the design of and materials for boiler mountings, such as water gauges, safety valves, stop valves, etc., for on these fittings the success of high pressures largely depends.

As riveted steam drums require exceptional care in manufacture, solid-drawn steam drums have been preferred for pressures of 600 lb. and upwards. Although the Langerbrugge drums have been made riveted, and have proved to be quite satisfactory at 800 lb. pressure, the care necessary in their construction made them almost as costly as solid-drawn drums.

Comparative Costs.—Assuming a fuel value of 18,500 B.Th.U. and 25 per cent. thermal efficiency, with oil-fired boilers and oil at £3 5s. per ton, the cost of fuel for producing 1,000 s.h.p. is about 193 pence, and compared with 30 per cent. thermal efficiency, and oil suitable for a Diesel engine at, say, £4 per ton, the cost of the latter will be 196 pence. The saving in fuel cost per s.h.p. in the boiler installation, with high pressure and superheat, may even be anticipated to be about 2 per cent. compared with the fuel cost per s.h.p. with Diesel engines, and I have no doubt that seagoing plants, in which the advantages of the steam engine will be obtained at no greater expenditure for fuel and much greater convenience and elasticity, will soon become general.

With coal burning the comparison would be still more favourable, and the cost of fuel would be about 143 pence per 1,000 s.h.p., with coal at 25s. per ton and 11,000 B.Th.U. heating value, and this allows for the falling off in boiler efficiency due to hand firing, but in the most modern marine installations mechanical stokers are introduced, which would still further considerably reduce the fuel cost.

The following paragraphs are from the "Liverpool Journal of Commerce," of June 3rd.

Reorganisation of Shipbuilding Industry. — There is a natural assumption that the final report of the Joint Committee of employers and representatives of shipyard unions will contain definite recommendations concerning the reorganisation of yard operations and reforms in other directions, with the object of reducing shipbuilding costs and inducing shipowners to place orders for new tonnage. It is the opportunity of laying new keels which is the primary requirement at the present time, when old work is being completed and new contracts assuming the rarity of angels' visits. It will be recalled that in the interim report of the Joint Committee a number of definite practical suggestions were made, the wisdom and expediency of which have not been challenged, notwithstanding that the shipyard unions deferred action until the inquiry was completed and the final report presented. As that report should be available in the near future trade union representatives will be called upon at an early date to show whether they have the courage to recommend for acceptance a number of changes in working conditions, details of which were in the interim report, and which must make an appeal as being necessary in the interests of every man engaged in shipbuilding. The recommendations covered questions in connection with continuity of work, interchangeability and substitution in cases of shortage of craftsmen. Many examples of continuity of labour which would tend to reduce production costs were given in an appendix to the report, and the examples quoted of work of an interchangeable character were even more numerous. The suggested reforms applied to shiprepairing as well as shipbuilding, and are an outstanding demonstration of the care with which the whole of these questions were examined by men who have an intimate practical knowledge of the technique of shipyard practice.

Report of Northern Federation Alliance. — Meanwhile another report has made its appearance. It refers to the shipbuilding and coal and iron and steel industries, and is the work of the Northern Section of the National Alliance of Employers and Employed. No surprise has been created by the fact that some of the recommendations made follow the same lines as those put forward in the interim report of the Joint Committee of the shipbuilding industry. Stress is laid on the effect in swelling costs of manufacture of too rigid adherence to demarcation rules, the need of greater use being made of labour aiding machinery, the desirability of a wider adoption of the system of payment by results, the placing of checks on unrestricted output, the importance of cheap fuel and lower charges for transport, and the reduction of national expenditure. It is a safe prediction that some of these recommendations will be repeated in the final report of the Shipbuilding Committee. All these are points which bear very closely on the revival of shipbuilding. Not only has the shipowner to be attracted into the new tonnage market by proof being given that costs in British yards have been got down to the lowest level possible, but home shipbuilders must be put in a position to offer effective competition with foreign yards, and not only prevent the diversion abroad of work for British shipowners, but attract a large share of the orders on foreign account, which used to occupy an important place in the activities of home shipyards. In addition to the general matters referred to above as reforms essential to the recovery of British industry, the final report of the Joint Committee will doubtless lay stress on the need of supplies of shipbuilding material and equipment being available at lower prices. Here, of course, the shipowner can help by waiving some of the very rigid clauses of his contracts, and allowing shipbuilders to obtain a number of items of equipment on competitive and not monopoly terms. The shipping and shipbuilding industries are to a great extent partners in the same enterprise, and if the new tonnage required to make the British merchant fleet the newest and the most efficient in the world is to be obtained at prices which will prove attractive, the leaders of the two industries have to pull together rather than take up the positions of buyer and seller. A prosperous and active shipping industry is impossible without it has behind it or beside it a virile and successful shipbuilding industry. The two are independent to an extent which is not always fully realised. In addition to making internal reforms in organisation, systems of working, and, where necessary, equipment, shipbuilders require the co-operation of shipowners. One cannot doubt that it will be given freely and in full measure.

Shipowners and Commercial Aviation.—In his address to the Southampton Chamber of Commerce, which was reported in "The Journal of Commerce," Sir Sefton Brancker made a point which has been presented many times in these notes. It is that the shipowning industry should take a prominent part in the work of the development of transport by air. As to the scope of this industry, of which only the initial stages have as yet been accomplished, the statement that since 1919 British aircraft have flown 4,750,000 miles and carried 700,000 passengers, as well as a considerable tonnage of goods, will indicate the traffic expansion which would be possible if the big shipping companies were to take a hand. The airship scheme, which is being backed by the Government, will initiate air transport on the Empire routes, for which at present the ship is the only method. Sea transport should not be displaced, but rather stimulated by the alliance with it of air transport to carry over long distances passengers and cargo of special kinds, at the high prices which it should be possible to charge for rapid transport at each end of the main sea routes. The precise role of the airship, the flying boat, and other types of aircraft in relation to the sea-going ship can only be determined by experience. One advantage which shipping companies would possess over independent enterprises is that they have established the organisation and possess the personnel required to handle transport business, and would not leave to start *de novo.* Sir Sefton Brancker impressed on dock and harbour authorities the need of giving attention to the provision of facilities for aircraft at all the world's principal ports. He emphasised the fact that the lead in long distance air transport should, as a matter of right, be undertaken by a maritime Power such as Great Britain.

Oil Pollution Congress.—The Congress which is to be held at Washington to frame international action in connection with oil discharge will have the opportunity of rendering useful service. It is a subject which has occupied the attention of shipowning organisations and public bodies on many occasions, and came up for discussion at the recent International Shipping Congress. The Liverpool Steam Ship Owners' Association appointed a committee, which has given special consideration to the problem and made certain definite recommendations. In his contribution to the subject, which appears elsewhere in to-day's issue, Mr. Sandford Cole, referred to the proposal that the fitting of oil separators on board ship should be made compulsory, as this remedy would deal with the evil at its source. It has been suggested that the forthcoming conference should recommend legislation to this effect in all maritime countries. There is, of course, general agreement that identical regulations should be brought into force in all countries, but the Liverpool committee expressed the opinion that the compulsory fitting of separators is undesirable. The action suggested by that committee is that any regulation—which should apply only to crude petroleum, fuel, and Diesel oil—should prohibit the discharge of oily ballast water and tank washings by all vessels other than naval craft within 150 miles from shore. The case of naval vessels would, it is assumed, be dealt with by Admiralty authorities. If this regulation went through, it is thought the whole difficulty could be overcome through the provision by port authorities of separating barges or other receptacles in adequate number, and that the need for the fitting of separators on ships would disappear. The International Committee has not laid down any hard and fast rules. It is stated in their report that the trouble is being gradually minimised. Admittedly, however, the holding of the Washington Congress is a good move, and if identical international regulations can be framed, the problem will no doubt be solved. The increase in the use of oil fuel renders it imperative that steps should be taken to end the practice of indiscriminate oil discharge. Voluntary action has achieved much, but it is a question for international regulations.

"Bye-Products" of Oil.—The news that the membership of the Boilermakers' Union has fallen by a matter of eight thousand is a reminder that the miners are not the only ones to suffer in an age of oil, although the fact that so much of the oil is burned under boilers is evidence that the economic burden upon the boilermakers is not yet so severe as that which afflicts the coal trade. If the whole British Mercantile Marine turned forthwith to oil, some boilers would still be needed. At the same time, the changes which recent years have seen in the science of ship propulsion have had very far-reaching effects in quarters of which little is usually heard. It is easy for the general public to realise that the conversion to oil of a big ship like the Mauretania, which had previously absorbed practically the whole output of a large mine, meant that that mine had either to find another customer or else go out of business. It is not so generally realised that the decision to fit Diesel engines in the Asturias meant not only that there was no hope of selling coal to the Royal Mail Steam Packet Company on her account, but also that a number of harmless necessary boilermakers lost several months of work; that the makers of feed pumps, lagging materials, boiler mountings, and even such minor equipment as firing tools and hydrometers, were likewise faced with a reduction of their means of livelihood. It is almost as certain that a few at least of the annual stream of inventors of boiler accessories have been obliged to turn to other possible markets or to allow their precious and hardly-won patents to lapse for lack of the wherewithal to keep them going. The making of a Diesel engine is a complicated business, but it is doubtful whether its beneficial effect in this country is as widespread as the loss occasioned by the abandonment of steam, regarded in the light of engineering employment.

To Solve the Coal Problem.—An important statement on the coal problem has been issued by Sir George B. Hunter, K.B.E., chairman of Swan, Hunter and Wigham Richardson, Ltd., the well-known shipbuilders.

Summing up the situation, Sir George says: There is no longer even the excuse of endeavouring to avoid the loss to the country entailed by a stoppage of work for delaying longer to face the real fundamental needs of the situation. The true problem is not a specifically coal problem, but one in which industry as a whole is concerned. It may be stated as follows:

1. The depression in the coal industry and in the other great industries of the country is due almost entirely to the fact that the products of our industries have been supplanted in the world's markets by goods produced abroad at lower costs owing to longer hours of work and lower rates of wages.

2. Our trade can be regained by such modifications of working conditions in this country as will enable us to compete on more nearly equal terms with foreign producers. The most urgently necessary of these changes in the case of the coal industry is the restoration of the eight hours day underground in the mines.

3. Wages and working conditions in sheltered occupations must be reviewed with the view of securing a fairer distribution of wages as between workers in the productive industries exposed to foreign competition and workers in sheltered occupations.

4. The results of political interference in industry during the past few years have been disastrous, and the Government should set its face definitely against the false theory that by interfering with the conduct of the industry they can either assist in removing industrial unrest or foster industrial progress. Experience proves that they only aggravate the one

and hamper the other; and the best service they can now render in the present crisis is—

1. To repeal that Seven Hours Act of 1919 and thus leave the parties themselves in a position effectively to negotiate an economic settlement of the mining dispute.

2. To abandon the idea of placing the coal industry in leading strings as suggested in the report of the Coal Commission, and to rely on the spirit of progress which is innate in industry to continue the record of successful achievement which has always been the proud boast of the coal industry in common with British industry generally. The proposed policy of Government bureaucratic interference, regulation and restriction, which is midway between nationalisation and free competition, might well prove worse than nationalisation itself.

Coal or Oil?—Presiding at the annual meeting of the Nitrate Producers' Steamship Co., last week, Sir John Latta, Bart., discussed the pros and cons of the steamer-Diesel controversy. Sir John said:—

After full deliberation we have contracted for two new steamers similar to the "Anglo Indian," in preference to Diesels. The latter I believe to be as efficient and likely to prove as durable as the steam engine, are independent of coal strikes, and what is almost as expensive, the perennial threatened strike, have a wider range of economic possibilities, and from the manager's point of view easier to operate. There are, however, many other considerations, and where a speed of 10 to 11 knots suffices, and the purpose general trading, we are of opinion that on to-day's capital and present working costs, steamers fitted with quadruple engines using superheated steam, show a higher return on the capital involved.

Diesels can carry, or rather are forced to carry, bunker oil in their ballast tanks. When cargo is unobtainable this is not an unmixed blessing, particularly when the quantity of fuel is limited to that required for an Atlantic trip in winter time. To-day there is a great shortage of outward and intermediate cargoes, entailing many trips in ballast. Coal bunker capacity does not add much to capital cost, and the substantial weight of the fuel gives the steamer a grip of the water. A Diesel vessel of 9,000 tons capacity, with electric auxiliaries, costs roughly £35,000 more than a steamer of 10,000 tons capacity. In the vicissitudes of trading the special mercantile properties of each are about equally divided. Diesels in the European trade lift bunker oil abroad for the return journey, thus shut out cargo on the slant upon which freights are highest, lessening to a slight extent their apparent extra earning power.

Moreover, in the main, the price of coal, relative to oil, seems the more likely to decline. That raises a very important factor for the consideration of colliery proprietors in marketing virgin coal. When bunker coal held the field, they at certain virgin coal centres abroad could with impunity ignore first cost and exact undue profits as opportunity admitted. Those days are, however, past, and the change makes it incumbent on them in their own interests to act reasonably and come to the assistance of the steamer in its fight with the Diesel, especially in the southern Hemisphere, viz., Chili (Coronel), the Cape, Australia, and New Zealand.

Unfortunately, at the most vital point, viz.: Natal, far from recognising the plight of the steamer, suppliers, in defiance of all economic laws, and of their obligations to old clients, subsidise coal exports by a heavy surcharge on bunker coal. The principle they adopt automatically exposes its injustice. For export coal their f.o.b. price is 15s., while bunkers for the transporting steamer are supplied at about the same price. On the other hand, if a steamer calls for bunkers only, the extortionate price of 27s. 6d. per ton is exacted. Coal cannot compete with oil on such terms. In 1915, the cost was 16s. 6d., and the restoration of that figure is long overdue. I have been told that the Central South African Railways are the real culprits. If that is so, I think our Government should make friendly representations to the Cape Government on the subject. It is of paramount importance to the British Empire that coal should remain the cheapest power producer. The arbitrary differentiation mentioned constitutes a grave injustice to the shipowner at an extremely crucial period in the history of the steamship.

The following is quoted from "Syren and Shipping" of June 23rd:—

The Marine Department of the Board of Trade have issued an important notice concerning Circular 1647, according to which passenger steamships using oil fuel are required to carry an apparatus for determining the flash point of the oil supplied to the ship. When this circular was issued there was no standard apparatus for this purpose, and accordingly, on the recommendation of the Departmental Committee of 1920, it was provided that the Abel tester cup, approved by the Board, might be used for this purpose until a standard apparatus had been devised. A specification of such a device has now been prepared by the Standardization Committee appointed by the Institute of Petroleum Technologists. The apparatus, which is designed for testing petroleum having a flash point above 120° F. is described as the "Standard Pensky-Martens Tester," and will be certified by the National Physical Laboratory. It is now on sale, and where new apparatus for this purpose is required for use on passenger ships, it must be of a type tested and certified by The National Physical Laboratory, such as the type named. No objection, Board of Trade Surveyors are advised, need be raised to the continued use of plant which has already been supplied, or purchased for supply, to passenger ships using oil fuel, provided it conforms to the requirements of Circular 1647. With regard to the working of the Pensky-Marten device, the oil to be tested is heated in an air bath, which may be either a flame-heated metal casing, or an electrical resistance element; the important point in either case being the rate of heating. The standard specification for the electrical heater has been drawn up by the Petroleum Department and agreed to by the Institute of Petroleum Technologists, and heaters complying with the specification can now be obtained. Each is marked with the voltage for which it is constructed, which should be the same as the voltage of the electrical system on board the ship, and the heater should always be used at the proper voltage. Purchasers are advised that full instructions are supplied with such apparatus, and it is essential that the instructions should be carefully adhered to, otherwise incorrect results may be obtained.

BOILER EXPLOSION ACTS, REPORT 2770.—While on a voyage from Newcastle-on-Tyne to Genoa, off Cape De Gata, an explosion occurred in one of the two main boilers of the *Blairmore*.

The boiler, built in 1901, was 15 ft. diam. by 10 ft. long, with three plain furnaces, steam pressure 160 lbs. In January, 1924, a wasted part of the centre combustion chamber back plate of the starboard boiler was reinforced by electric welding round the bottom starboard stay. In January, 1925, several defective smoke tubes were renewed, three stay holes in the centre combustion chamber side plate were built up by electric welding on the water side of the plate, and the landing edge of the riveted joint of this plate was also built up. When off

Cape De Gata, in the morning a severe hissing sound was heard, and about half an hour later water issued from the centre furnace of the starboard boiler, and gradually increased to such an extent that the fires had to be drawn and the boiler emptied. Examination revealed the cause of the leakage to be due to a hole in the back plate of the centre combustion chamber, adjacent to the electric welding which was done in January, 1924.

On hammering the plate lightly the hole increased to $\frac{3}{4}$ in. diam. fully. An attempt was made to plug the hole with a bolt and washer plate, but due to the badly corroded surface on the water side, a tight fit could not be managed, and so steam from the port boiler was used to carry on to Cartagena, where the defective portion of the plate was repaired by a patch electrically welded.

On return to the Tyne the defective lower portion of the back plate was cut away and a new portion fitted. The boiler was afterwards tested by hydraulic pressure to 200 lbs.

The investigation was conducted by Mr. R. F. Manson, Board of Trade Surveyor.

The observation made by the Engineer Surveyor-in-Chief was to the effect that the repair carried out in 1924 was not so thorough as it should have been, and the water side of the plate was not closely examined to ascertain its condition. The removal of the bottom portion of the plate was well advised.

READING ROOM AND LIBRARY.—A donation of £2 is acknowledged with thanks to Robert Clark, Member.

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Books added to the Library.

By the courtesy of The Superheater Co., Ltd., 195, Strand, W.C.2. "Superheat Engineering Data." — This is a very useful handbook, containing in a compact form a great variety of information on the subject of superheated steam, and many tables are included, with curves and graphs, showing the effects of superheat upon consumption and efficiency, radiation losses, steam velocities, pipe areas and diameters, etc., in addition to several useful tables of weights and measures and similar general information. The book is also useful for its illustrations of the many varieties of water tube boilers now in use, most of them variants of the three well-known parent types of

Yarrow, Babcock and Wilcox, and Stirling, which have, it appears, generated a numerous progeny, distinguished by a great number of different names, but still bearing a very strong resemblance to their progenitors. The book is published at 5/- and is very good value for anyone concerned with high pressure or superheated steam installations.

"BULK CARGOES." By A. C. Hardy, B.Sc., A.M.Inst.N.A., A.M.I.Mar.E. London, Chapman and Hall, Ltd., 11, Henrietta Street, W.C.2. 21/- net.—This volume is not written so much for the marine engineer as for the naval architect and the superintendent, but it will have for all engineers the attraction of a book written by a man who knows his subject. The various types of cargoes are dealt with adequately, their methods of loading, stowage and discharge are clearly explained and illustrated, and the various forms of ship construction which have been evolved to carry them most efficiently are described, with drawings. Not the least among the attractions of this book are the stout paper, the excellent illustrations, the fine clear type, and the really good English which the author commands. If marine engineers do not feel that the subject is sufficiently close to their proper sphere to warrant the study of this book, we can still recommend him to obtain it for its accuracy, its general interest to all sea-faring officers, and for the attractions above mentioned.

The Appendix I., dealing with casualties to colliers during the years 1922, 1923 and 1924 will serve to remind many of the grave dangers which attend the carriage of bulk cargoes without adequate precautions, and Appendix II. gives a copy of the "Second Report of the Informal Committee on Coal Carrying Vessels" of April 10th, 1924, which will be found both interesting and instructive by all who go down to the sea in ships.

"REED'S MACHINE DRAWING FOR MARINE ENGINEERS." By H. H. R. Daish, John Forrest and Joseph H. Sword, Extra 1st Class Engineers, of the Marine School of South Shields. Sunderland, Thos. Reed & Co., Ltd., 184, High Street, W. 10/- net.—This is the first work of its kind that we have seen since the method of drawing from perspective illustrations was introduced by the Chief Examiner of Engineers at the Board of Trade Examination. There can be no doubt that this method is of great value to marine engineers who have not had the necessary drawing office experience, for we have known of cases of marine engineers who could understand and reproduce a drawing already made, but who could not produce a working drawing of a part of an engine or boiler when repairs or renewals have been required. The new method of preparing a working drawing from a perspective or pictorial representation is, of course, much better training for those who are required to make a sketch of an object already in existence, as distinct from the draughtsman who first designs the object, and who has no model but his own conception.

The book under review is designed to teach the new method and we think it is very well designed to that end. The preliminary chapter on the principles of projection is very well arranged and will be of great assistance to the student. The drawings represent a wide range of subjects, including some of the more difficult examples. They are produced in an excellent manner and adequately explained. We very willingly recommend this work to all young men desirous of mastering the principles of drawing as required for the Board of Trade Examinations.

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Election of Members.

List of those elected at Council Meeting of June 14th, 1926.

Members.

Francis Allan, *c/o* Nielson and Malcolm, Hankow, China.

Harold Southwell Caswell, Harbour Engineers' Dept., Colombo Port Commission, Colombo, Ceylon.

William Sharp Cobb, 75, Dacre Road, Upton Manor, E.13.

Benjamin Harold Davison, "Tyneside," Ifield Road, Crawley, Sussex.

John Paris Duguid, 8, Spring Street, Sydney, N.S.W.

Henry McKie, *c/o* T. Murray, 50, Kent Road, Glasgow.

Philip Arthur Pickett, 26, Park Street, Southwark, S.E.1.

Thomas William Rose, Chief Engineer, Sunnyside Mental Hospital, Christchurch, N.Z.

Robert Drayton Thrower, C.S. "Lady Denison-Pender," *c/o* Eastern Telegraph Co., Ltd., Zanzibar.

Richard John Wolfe, 8, Richmond Road, Cardiff.

Associate.

Frederick Samuel Margrie, Church Villa, Aust, Nr. Bristol.

Graduate.

Robert Milne Murray, 76, Grosvenor Road, Ilford, Essex.

Transferred from Graduate to Member.

James W. Campbell, 37, Forest Drive East, Leytonstone, E.11.

Transferred from Associate to Associate-Member.

D. W. Freemantle, 102, Humber Road, S.E.3.

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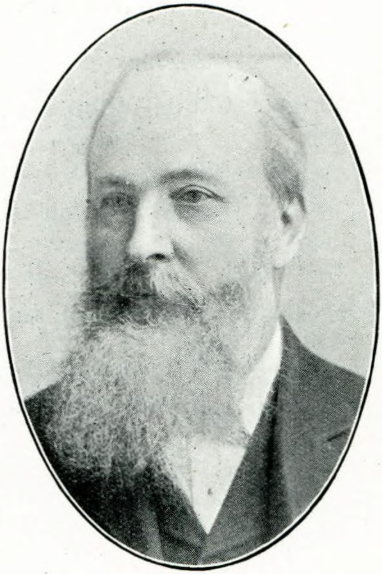

Jas. Girvin, one of our early members, who gave his name in the winter of 1888, while the Institute was in course of formation, died at Carrickfergus on June 7th, to the great regret of those who were associated with him and by whom he was highly esteemed.

He was born at Carrickfergus on January 9th, 1837, received his education at a local school, then served his apprenticeship in Walker's Textile and Spinning Works and in Coombes' Works, Belfast. Subsequently he served in A. & J. Inglis' Engine Works, Glasgow, then went to sea in the days when the boiler pressure was about 20 lbs.

After gaining sufficient experience he joined the British India S.N. Co. in September, 1867 as Chief Engineer of the *Dacca*. He served in other steamers of the Company, including the *Quetta*, which he left the voyage before she was lost off the Queensland coast in 1889, when all the engineers held on to their duty in the engine-room and were drowned. Mr. Girvin retired in January, 1906, after nearly 40 years faithful service in the Company. He was unmarried and his niece attended to his welfare during his retirement.